SCIENCE on Stage 1 & 2

Demonstrations and teaching ideas

selected by the Irish teams



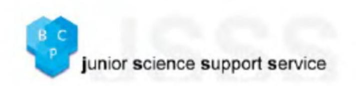














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Demonstrations and teaching ideas

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I hear and I forget. I see and I remember. I do and I understand.
Confucius

The whole of science is nothing more than a refinement of everyday thinking. The most beautiful thing we can experience is the mysterious. It is the source of all true art and all science. He to whom this emotion is a stranger, who can no longer pause to wonder and stand rapt in awe, is as good as dead: his eyes are closed.

Science is facts; just as houses are made of stone, so is science made of facts; but a pile of stones is not a house, and a collection of facts is not necessarily science.
Jules Henri Poincaré

Theory guides. Experiment decides
Unknown

Every experiment proves something. If it doesn't prove what you wanted it to prove, it proves something else.
Unknown

Disclaimer

Any comments or suggestions would be welcomed by the committee and can be sent to the Chairperson: Dr. Eilish McLoughlin, Science on Stage, CASTeL, School of Physical Sciences, Dublin City University, Dublin 9, Ireland. Email:irelandsos@gmail.com

www.scienceonstage.ie

CONTENTS

TOPICS

Foreword

It is a pleasure to introduce this science teaching resource which presents demonstrations and teaching ideas prepared and selected by the Irish Science on Stage committee and teams that attended the Science on Stage 1 festival in CERN, Geneva from 21-25 November 2005 or the Science on Stage 2 festival held in Grenoble from 2-6 April 2007.

The Science on Stage programme is an innovative, pan-European science education activity, designed to foster a renewal of science teaching in Europe by encouraging the exchange of new concepts and best practice among teachers from all over the continent and follows from the success of the three editions of the Physics on Stage programme from 2000 to 2003. Innovative and inspirational science teaching is seen as a key factor in encouraging young people to engage with scientific issues. Hence, Science on Stage aims to stimulate the interest of young people through the school teachers, who can play a key role in reversing the trend of falling interest in science and current scientific research. Each programme culminates in a week-long festival, combining a science teaching fair with on-stage activities, parallel sessions and workshops. The teaching fair provides an array of vibrant and stimulating displays from thirty countries across Europe with a multitude of languages and enthusiastic participants who take every opportunity to exchange teaching materials and ideas.

This project was made possible by the generous sponsorship of the Second Level Support Service, Junior Science Support Service, Discover Science and Engineering, Institute of Physics in Ireland (IOPI) and EIROforum European Science Teachers' Initiative (ESTI) (a partnership between CERN, ESA, ESO, EMBL, ESRF, ILL, EFDA and supported by the European Commission). We would like to gratefully acknowledge the support provided for teacher substitution by the Department of Education and Science through the Second Level Support Service.

The gratitude of the thousands of teachers and educators who receive this free booklet of demonstrations and teaching ideas must principally go to the very hard-working team of authors: Siobhan Crowe, Noel Cunningham, Brendan Duane, Sean Fogarty, Rory Geoghegan, Alison Graham, John Hennessy, Damienne Letmon, Rachel Linney, Brian Masterson, Kevin Murphy, Joe Nugent, Paul Nugent, Seamus Ó Donghaile and Tim Regan. In particular, sincere thanks to Paul Nugent who has been energetically promoting the POS/SOS programmes and sharing demonstrations since POS1 and to Rory Geoghegan for his tremendous work in the arduous task of proofing and editing this booklet and working on it right through to the final stages of production.

All of these teachers work full time, yet, despite this, they tested and produced this excellent collection of demonstrations selected from the Science on Stage conferences and this publication would not have happened without their very professional commitment.

It has been my pleasure to work with these inspiring science teachers and educators in co-ordinating the SOS1 and SOS2 programmes and producing this booklet, which I hope you will find an invaluable classroom resource. For further information on Science on Stage in Ireland and for electronic copies of all the POS/SOS booklets, please visit: www.scienceonstage.ie

Dr. Eilish McLoughlin

Chairperson Science on Stage National Steering Committee

Email:irelandsos@gmail.com



SOS1 Team and Contributors

A team of nine delegates represented Ireland at the European Science Teaching Festival "Science on Stage 1" in CERN, Geneva from 21-25 November 2005. The team consisted of Eilish McLoughlin from CASTeL, DCU; Paul Nugent, Physics Teacher Coordinator with the IOPI/ St Dominic's High School, Santa Sabina, Dublin 13; Siobhan Crowe, Dominican College Wicklow, Wicklow; Seamus Ó Donghaile, Scoil Mhuire, Strokestown, Co. Roscommon; Alison Graham, Sandford Park School, Ranelagh, Dublin 6; Sean Fogarty, St. Mary's Secondary School, New Ross, Co. Wexford; Rachel Linney, Confey College, Leixlip, Co. Kildare; Damienne Letmon, Presentation College, Terenure Park, Dublin 6W and Tim Regan, Physics Coordinator with Second Level Support Service.



The Irish Science on Stage 1 team at CERN in November 2005

Back row:(l-r) Eilish McLoughlin, Siobhan Crowe, Alison Graham

Front row:(l-r) Tim Regan, Damienne Letmon, Rachel Linney, Seamus Ó Donghaile, Paul Nugent and Sean Fogarty.

SOS2 Team and Contributors

A team of eleven delegates represented Ireland at the European Science Teaching Festival "Science on Stage 2" in Grenoble 2-6 April 2007. The team consisted of Dr. Eilish McLoughlin from CASTeL, DCU; Paul Nugent, Physics Teacher Coordinator with the IOPI/ St Dominic's High School, Santa Sabina, Dublin 13; Brendan Duane, Chemistry Coordinator with Second Level Support Service; Joe Nugent, Chemistry Teacher Coordinator with the RSC, John Hennessy, Junior Science Support Service; Rachel Linney, Confey College, Leixlip, Co. Kildare; Damienne Letmon, Presentation College, Terenure Park, Dublin 6W; Rory Geoghegan, Oatlands, Mount Merrion, Co. Dublin; Brian Masterson, De la Salle, Churchtown, Dublin 14; Noel Cunningham, King's Hospital, Palmerstown, Dublin and Kevin Murphy, St. Paul's Secondary School, Greenhills, Dublin 12.



The Irish delegation at the Ireland fair stand at SOS2 festival

Back row: (l-r) Brendan Duane, John Hennessy, Rory Geoghegan, Kevin Murphy, Paul Nugent, Joe Nugent, Brian Masterson, Noel Cunningham.

Front row: (l-r) Rachel Linney, Eilish McLoughlin, Damienne Letmon.

Science on Stage 1: The Festival

CERN, Geneva from 21-25 November 2005

The SOS1 festival was attended by 530 delegates from 29 countries and was entitled Science for Humanity and involved five days of performances, demonstrations and workshops around daily themes, namely: Einstein Day; Space and Astronomy Day; Life Sciences Day; Sustainability Day and Technology in Society Day. "At the festival, teachers have the chance to view things from a new perspective, to be entertained and enchanted by science", says Rolf Landua, Head of Education at CERN and Chairman of the event. "As well as taking to the stage, they set up stalls in fair-like surroundings to share their most successful teaching tricks." The complete festival programme is available by visiting the SOS1 website at http://science-on-stage.web.cern.ch/science-on-stage/

The nine-strong Irish Science on Stage delegation were involved in a variety of workshops and prepared an inspirational display initiated by team member Alison Graham to demonstrate "Teaching Science as a Product" and "Teaching Science as a Process". The Irish delegation was honoured to receive one of seven EIROforum Science Teaching Awards in recognition of their contribution for "teaching excellence, inspiration and motivation of young people in a contribution to the Science on Stage festival". The award included a visit by the delegation hosted by EFDA/JET in Culham, UK.

Minister for Education and Science, Mary Hanafin recognised the award and the activities of Science on Stage in Dublin in December 2005, remarking on the, *"emphasis placed on the use of simple equipment to demonstrate the most fundament physical concepts in a way that fascinates everyone, regardless of their background in science. What struck me also was the way in which science can be investigated and demonstrated with everyday objects and materials – it really brings home the fact that science is all around us and that so many aspects of our lives depend upon it"*.



Back row: (l-r) Rachel Linney, Siobhan Crowe, Damienne Letmon, Sean Fogarty, Seamus Ó Donghaile and Paul Nugent

Front row: (l-r) Tim Regan, Mary Hanafin T.D., Eilish McLoughlin, Alison Graham.

Science on Stage 2: The Festival

Grenoble 2-6 April 2007

The Science on Stage 2 Festival took place in Grenoble, which is the leading centre for research in France outside the Paris area. About 20% of its active population is involved in research, higher education and advanced technology. Grenoble hosts nine national research organisations, two major international facilities and three European laboratories, four universities and sixteen engineering schools, which makes it a truly inspiring location for a gathering of over 600 science teachers and educators. During the festival, the delegations availed of the opportunity to visit three of the research centres: Institut Laue-Langevin (ILL) which specialises in neutron science and technology, the European Synchrotron Radiation Facility (ESRF) which produces extremely powerful X-ray beams and the European Molecular Biology Laboratory (EMBL).



The Irish team were commended for their week-long fair presentation entitled "**Reduce, Reuse, Recycle** – A selection of demonstrations to show innovative approaches to teaching science using recycled and reusable materials and promoting environmentally friendly solutions". Examples included wind generators, solar energy, bionic plungers, density of air, colour mixing, smelly balloons, electrolysis, wave motion using reclaimed components from household appliances, air rockets, energy conservation and much more. The Irish team also presented a **workshop** on the Effective use of technology in Science Education, showing how data loggers, sensors, computers and virtual learning environments have been used with our curriculum to improve student understanding.

Other highlights of the festival included the **on-stage performances**, examples include, Molecular Gastronomy, The secrets of sea depth, Experiments between magic and science and Top ten myths where lots of science questions were raised, e.g. "What is the Coriolis effect and does it have anything to do with plug-holes in Australia?" "Can science help us go ghost-busting?", "Can mobile phones cook an egg - or your brains?", and "What do glowing gherkins have to do with astronomy?". The festival programme also included for the first time a **round table discussion** on "European Science Education in the age of the knowledge Society - Strengthening Science Education in Europe", chaired by the European Commissioner for Science and Research. The complete programme for the festival can be found from: http://www.esa.int/SPECIALS/Science_on_Stage/index.html

Biology

Kiwi DNA

Separation of DNA from plant tissue

You will need....

- ✓ Kiwi fruit (ca. 100 g)
- ✓ coffee filter
- ✓ beaker (250 ml)
- ✓ ice-cold ethanol (10 ml)
- ✓ salt (3 g)
- ✓ funnel
- ✓ distilled water (100 ml)
- ✓ conical flask
- ✓ washing up liquid (10 ml)
- ✓ thermometer
- ✓ hot water bath
- ✓ wooden splint
- ✓ syringe
- ✓ 250 ml beaker



Background:

In this experiment the nuclear membrane and the cell membrane is broken down to allow the DNA to be collected. To collect the DNA the protein has to be removed by a protease enzyme. This is not required with a kiwi fruit as it has its own protease enzyme which breaks down the protein. It is therefore safer to use the kiwi fruit as the protease could damage your hand.

Follow these steps:

1. Place the chopped kiwi fruit into the beaker.
2. Dissolve the salt in 20 ml distilled water. Add the washing-up liquid. Make up to 100 ml with distilled water.
3. Add this mixture to the kiwi and place in a hot water bath at 60ºC for 15 min.
4. Remove the beaker from the water bath and place in ice-cold water for 5 min.
5. Filter the mixture through coffee paper.
6. Add 10 ml of the filtrate to a clean boiling tube.
7. Add the ice-cold ethanol from the freezer gently down the side of the boiling tube.

So what happened?

The washing-up liquid destroys the cell membranes while the salt causes the DNA to clump together. Enzymes, which digest the DNA, will be denatured by the heat. The coffee filter paper has to be used to filter the mixture as the pores of lab filter paper are two small to allow the DNA pass through. The ethanol should float on top of the filtrate. The DNA will appear as white threads and floats up into the boundary area between the ethanol and the filtrate. DNA is insoluble in ice-cold ethanol.

What next

1. Try to extract DNA from other plant material?



Biology

Dead or alive?

Establish whether the peas are living or non-living

You will need....

- ✓ Some peas
- ✓ water
- ✓ A container and lid
- ✓ Splints and lighter
- ✓ Eager students!

Background:

All living things share seven characteristics: growth, respiration, movement, nutrition, excretion, reproduction and response. However it can be difficult to observe some of these characteristics. It may not be obvious that seeds, including peas, are alive.

Germinating plants respire, taking in oxygen and producing carbon dioxide. Carbon dioxide does not support combustion.

Follow these steps:

1. Ask the students some questions about living and nonliving things before asking if peas are alive.
2. For the experiment give the students a container, put some peas inside with a little water and secure the lid. Challenge the students to prove that the peas are alive.
3. With a little time and discussion the students should be able to put the pieces together and conclude that if the peas are alive and have had some time to respire the available oxygen will be depleted and replaced with carbon dioxide.
4. If the peas are alive the environment within the container should extinguish a lighted splint.

So what happened?

As the peas soaked up the water the conditions were right for germination. As they germinated, oxygen was depleted and carbon dioxide was produced. A lighted splint was extinguished when inserted into the container showing that the oxygen concentration was reduced.

What next?

1. Try this with other seeds. Will this work without the water?
2. Why will the same test not work with a seedling or adult plant in a sealed jar?
3. How many of the characteristics of living things are demonstrated?



Biology

Negative geotropism vs. phototropism

Which is the dominant influence on growing shoots?

You will need...

- ✓ a platform (e.g. a bicycle wheel) rotating on a horizontal axis
- ✓ growing medium (compost) held in a mesh
- ✓ seeds (e.g. cress)

Background:

If plants are grown on a vertically rotating platform then the direction in which they experience the gravitational force of the Earth keeps changing. If a light source is placed on one side (along the axis of rotation) then the shoots will grow towards the light.

Follow these steps:

Mount a bicycle wheel so that it can be rotated by a variable speed motor continuously for a few weeks. Mix the seeds with the compost and bind it to the rim of the wheel using a loose mesh. (Alternatively, the mixture can be placed in lengths of loose nylon stockings and then attached symmetrically to the wheel rim.)

Taking the radius (r) as 25 cm then the critical speed of rotation can be found from:

$$r(2\pi / T)^2 = g$$

This gives

$$T = 1 \text{ s}$$

(where $\boldsymbol{T}$ is the time for one rotation and $\boldsymbol{g}$ is the acceleration due to gravity.)

So what happened?

If the speed of rotation is large enough then the shoots will grow towards the centre of rotation.

What next?

1. Try speeds of rotation above and below one revolution per second.
2. Devise an experiment to investigate the relative influence of light and gravity.



Biology

Human blood

An activity to model the human circulatory system

You will need....

- ✓ Large hall
- ✓ Gym mats or chalk,
- ✓ Coloured paper for O_2 and CO_2
- ✓ Stopwatch
- ✓ Whistle
- ✓ A class of active students

Background:

Students often have difficulties understanding the circulation system in the human body. In this activity the students play the part of the blood and simulate the distribution of oxygen and the removal of carbon dioxide.

The activity is best carried out after the subject has been introduced and the students have some familiarity with the circulatory system.

Follow these steps:

Place the mats or mark the floor with chalk to represent the Lungs, the Heart (two parts) and the Body, as shown in the diagram. Mark out the arteries and veins.

Place the O_2 cards on the lungs and the CO_2 cards on the body. The students move in a single line in the veins and in pairs (pulsed) in the arteries. They pick up the coloured paper (O_2) in the Lungs and deposit it in the body. In the Body they pick up CO_2 and transfer it to the Lungs.

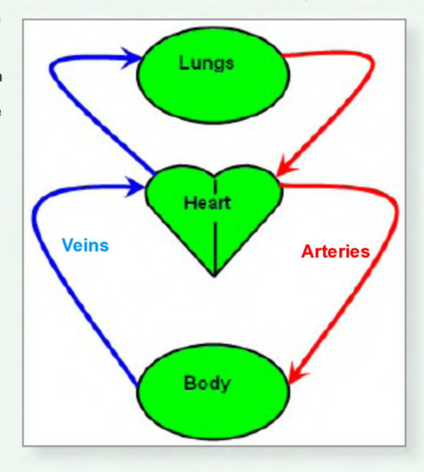
At any time the whistle can be blown and some students may be asked 'where they are' and what they are carrying.

So what happened

Oxygen and carbon dioxide are continually exchanged in the circulatory system.

What next?

1. Students can be asked to move faster so that blood is moved around more quickly and the 'pulse' recorded.
2. The names of the blood vessels can be included.
3. Ask the students what else can be done to improve the model (e.g. how to replenish the supply of 'oxygen' and 'carbon dioxide').



Now you see it, now you don't

An oscillating chemical reaction

You will need....

- ✓ 75 cm^3 of concentrated sulfuric (VI) acid.
- ✓ 9 g of malonic acid
- ✓ 8 g of potassium bromate (V)
- ✓ 1.8 g of manganese (II) sulfate
- ✓ 750 cm^3 of deionised water.
- ✓ Magnetic stirrer
- ✓ 1 dm^3 flask

Background:

Bromate ions oxidise malonic acid to carbon dioxide.

The reaction is catalysed by manganese ions.

This reaction will not work with tap water.

Clean apparatus is essential.

A white background is useful.

Follow these steps:

1. Put the deionised water in the flask.
2. Slowly add the sulfuric acid
3. Allow to cool
4. Place the flask of acid on a magnetic stirrer and stir fast enough to form a vortex.
5. Add the malonic acid and potassium bromate and allow them to dissolve.
6. Add the manganese sulfate and observe.

So what happened?

A red colour develops immediately. This disappears after about a minute and then the colour oscillates from red to colourless every 20 seconds. This continues for 10 minutes.

Safety:

! Wear eye protection. Great care should always be taken with concentrated acids.

! The reaction mixture can be washed down the sink with plenty of water.

What next?

1. Discuss the possibility of investigating this reaction using a colorimeter with an interface to a computer.
2. Compare the process to predator-prey relationships in ecology.





Chemistry

Colour in motion

An oscillating chemical reaction

You will need....

- ✓ 410 ml H_2O_2 (30%)
- ✓ 42.8 g KIO_3
- ✓ 40 ml H_2SO_4 (2 M)
- ✓ 15.6 g malonic acid
- ✓ 3.38 g manganese (II) sulfate
- ✓ 0.03 g soluble starch
- ✓ deionised water
- ✓ three 1 dm^3 beakers
- ✓ 500 ml conical flask

Follow these steps:

1. Dilute the H_20_2 with deionised water to 1 dm^3 (solution A).
2. Dilute the KIO_3 plus the H_2SO_4 with deionised water to 1 dm^3 (solution B).
3. Dissolve the starch in 50 ml boiling water. Allow it to cool.
4. Dilute the malonic acid plus the manganese (II) sulfate plus the starch with deionised water to 1 dm^3 (solution C).
5. Place 100 ml of each of solutions A, B and C in the 500 ml flask.
6. Place the flask on a magnetic stirrer and stir fast enough to form a vortex.
7. Observe the effect.

So what happened?

The colour oscillates from blue to yellow every 20 seconds. This continues for 10 minutes.

Safety:

- ! Wear eye protection. Great care should be taken with concentrated acids.
- ! The reaction mixture can be washed down the sink with plenty of water.

What next?

1. Discuss the possibility of investigating this reaction using a colorimeter and data-logging equipment.





Use water to kickstart a reaction

Effect of catalysts in chemical reactions

You will need....

- ✓ 20 g ethanedioic acid (oxalic acid)
- ✓ 10 g potassium dichromate
- ✓ pestle and mortar
- ✓ water
- ✓ dropper

Background:

A catalyst is something that alters the rate of a chemical reaction without being used up in the reaction. Here, water acts as the catalyst in the reaction between oxalic acid and potassium dichromate.

Follow these steps:

1. Grind the oxalic acid to a fine powder using the pestle and mortar.
2. Add the potassium dichromate and mix thoroughly.
3. Add one drop (yes one drop) of water and leave to stand for 2-3 minutes.

Safety

! Avoid handling the crystals of potassium dichromate or inhaling small particles of it.

So what happened?

A catalysed reaction occurs that lasts for about 30 seconds. A fume cupboard is not a necessity.

What next?

1. Find out more about the commercial applications of catalysts and how they work.



Chemistry

Chemilumimescence

Oxidation of luminol with bleach

You will need....

- ✓ 0.4 g luminol
- ✓ 4.0 g sodium hydroxide
- ✓ 100 cm^3 household bleach
- ✓ three 1 dm^3 conical flasks
- ✓ thermometer
- ✓ tap water

Background:

The energy of a chemical reaction can be given out as light or heat.

Follow these steps:

1. Mix the bleach and 900 cm^3 of water in one of the flasks and stopper it.
2. In the other flask put the luminol, 1 dm^3 of water and the sodium hydroxide. Swirl to dissolve the chemicals and then insert the stopper.
3. The luminol does not appear to dissolve completely, but forms a fine greenish suspension.
4. Lower the lights and pour the two solutions at the same rate into the third flask so that they mix on pouring.

So what happened?

A pale blue glow will be seen on mixing which persists for a few seconds. Take the temperatures of the solutions and the resulting mixture. They will be the same.

The darker the room the more obvious the effect, provided that the demonstrator can see well enough to pour!

The temperature can be monitored more conveniently using electronic sensors or dataloggers.

Safety

! Avoid contact with the sodium hydroxide or the bleach.

What next?

1. The solutions can be poured into a funnel attached to a clear plastic tube which can be bent into a variety of shapes. This can enhance the visibility of the demonstration.
2. Chemiluminescent 'light sticks' are used for emergency underwater lighting and fishing lures. They are also used in novelty items such as necklaces. The light sticks contain a glass vial containing one solution inside a plastic tube containing the other. The reaction is started by breaking the glass and the glow continues for some hours.

Grow a crystal garden

Colourful reactions of transition metals

You will need....

- ✓ Sodium silicate solution (waterglass)
- ✓ Hydrates of Iron (III), cobalt and sodium nitrates
- ✓ Hydrates of Iron (III), cobalt and sodium chlorides.
- ✓ Hydrate of copper sulfate
- ✓ Hydrate of nickel chloride
- ✓ Distilled water
- ✓ 500 cm^3 beaker

Follow these steps:

1. Dilute the waterglass with an equal volume of distilled water.
2. Pour the solution into the beaker.
3. Add crystals of the hydrates to the solution. Choose crystals that are as large as possible.

So what happened?

After a short while, lush 'vegetation' starts to grow from the bottom of the vessel

What next?

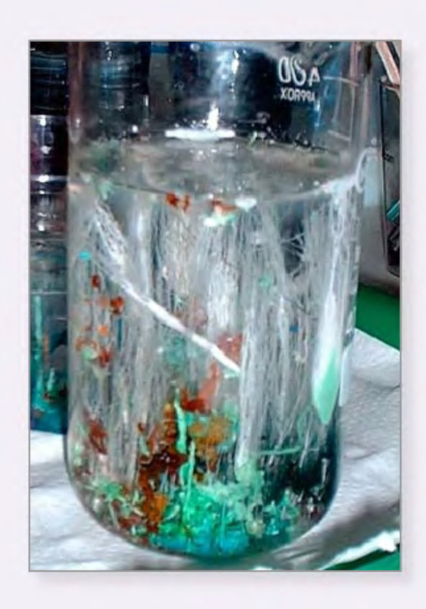
1. Note the colours formed; are they characteristic of the different metals present?

Background:

The reaction of transition metal salts with waterglass solution (sodium silicate) provides a very lush 'vegetation' chemical garden.

Safety

! Wear gloves when handling the solutions.



Chemistry

Desert survival

Evaporation as a separation technique

You will need....

- ✓ A urine sample
- ✓ 2 plastic bottles
- ✓ Adhesive tape

Background:

Urine is a mixture of water and many other substances, many of them harmful. It is possible to separate the water from a urine sample and drink this to survive.

Follow these steps:

1. Place the urine in one of the bottles.
2. Tape the second bottle to the first, neck to neck.
3. Very carefully tilt the bottles till they are horizontal. Try not to let the urine touch the dry bottle as this is the one you will drink from!
4. Lay the bottle on the sand, cover the empty bottle in sand and leave the one containing the urine exposed to the Sun.

So what happened?

The Sun heats the urine and the water evaporates. The gas (water vapour) moves across to the empty bottle. Here it is cooled as the sand shades this bottle. When the water vapour cools it condenses and turns back into a liquid which you can drink.

What next?

1. Investigate other methods to separate mixtures.



Tea time

Separation of mixtures by distillation

You will need ...

- ✓ 2 test tubes
- ✓ tea
- ✓ stopper with one hole
- ✓ stopper with two holes
- ✓ 3 short pieces of rigid tubing
- ✓ short length of flexible tubing
- ✓ beaker (250 mL)

Background:

Distillation can be used to separate liquids with different boiling points .

Follow these steps:

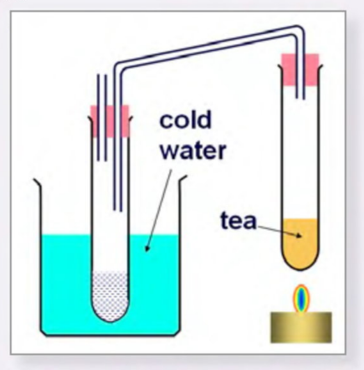
1. Place a small amount of tea into the first test tube and plug with a one-hole stopper. Insert a small piece of rigid tubing.
2. Plug the second test tube with the two-hole stopper.
3. Take the other two short pieces of rigid tubing and push them into the two-hole stopper.
4. Use the length of flexible tubing; connect the rigid tubing from one-hole of the two-hole stopper with the rigid tubing in the other test tube, as shown in the diagram.
5. Hold the test tube with the tea in a clamp and place the other in a beaker of cold water.
6. Place a tea light under the test tube with the tea.

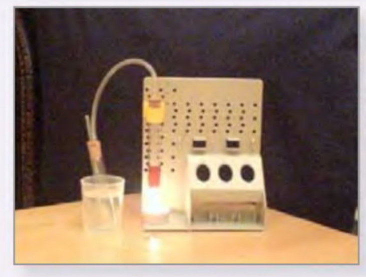
So what happened?

At 100ºC the water in the mixture of tea turns into steam. The steam condenses in the second test tube back to water.

What next?

1. Investigate the extraction of caffeine from cola.
2. Investigate how distillation is used in industry (e.g. alcohol, perfume, petroleum)





Chemistry

Exploding bubbles

The electrolysis of water

You will need ...

- ✓ 12 V DC power supply
- ✓ Connecting leads and crocodile clips
- ✓ 10 cm of platinum (Pt) wire
- ✓ 10 cm of copper (Cu) wire
- ✓ One bung
- ✓ glass tubing (right angle)
- ✓ flexible tubing
- ✓ trough or large beaker
- ✓ conical flask
- ✓ spatula
- ✓ 10 g sodium sulfate
- ✓ detergent

Background:

A dilute solution of sodium sulphate is electrolysed using platinum and copper electrodes. The hydrogen and oxygen evolved at the electrodes are mixed and used to blow soap bubbles. The bubbles can be ignited giving a loud 'crack'.



Follow these steps:

1. Put the glass tubing into the bung and connect the flexible tubing.
2. Insert the Pt and Cu electrodes into the bung and seal them with Vaseline or Blu-Tack.
3. Dissolve the sodium sulphate in 500 cm^3 of water.
4. Fill the conical flask with the sodium sulphate solution to the brim and fit the bung air tight.
5. Connect the electrodes to the power supply – positive to the platinum and negative to the copper. Increase the voltage until the current is 1 A.
6. Put the free end of the flexible tubing into a trough of water containing some detergent.

So what happened?

Oxygen will form at the anode and twice as much hydrogen at the cathode.

At the end of the delivery tube in the trough of water bubbles will form and collect at the surface of the water. Scoop up some bubbles on a spoon or spatula and ignite them. They will explode with a sharp crack.

Safety

! NEVER attempt to ignite the bubbles at the end of the delivery tube.

What next?

1. The gases could be collected separately using a Hoffman Voltameter or an electrolysis cell to confirm that the volume of hydrogen is double that of oxygen.
2. Add a few drops of universal indicator to the sodium sulfate solution so that the green colour is clearly visible. The indicator will turn blue around the cathode due to the formation of OH^- (aq) and yellow around the anode due to the formation of H^+ (aq) ions.

Cool fizz

An endothermic reaction

You will need....

- ✓ Thermometer
- ✓ Plastic cup
- ✓ Citric acid
- ✓ Sodium hydrogen carbonate powder (baking soda)

Background:

The neutralisation reaction between citric acid and sodium hydrogen carbonate is a good example of an endothermic reaction. In this experiment a temperature drop to minus 10˚C and below is achievable.

Follow these steps:

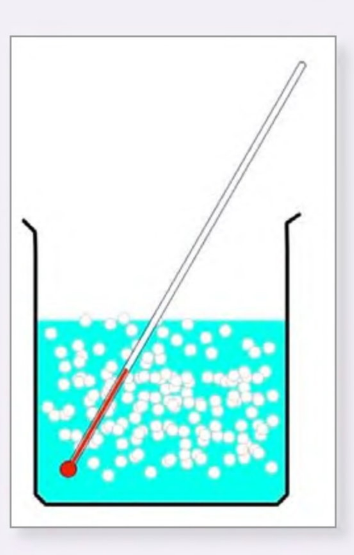
1. Make up a saturated solution of citric acid in the plastic cup.
2. Record the temperature.
3. Add the sodium hydrogen carbonate powder stirring with the thermometer.
4. Record the minimum temperature.

So what happened?

The mixture will fizz. The temperature will decrease as the reaction progresses. This is an endothermic reaction.

What next?

1. Write an equation for the reaction between the acid and the alkali and indicate which gas is given off.
2. Describe in terms of bond breaking and bond making, why some reactions are exothermic and some are endothermic.



Chemistry

Blow your top

The explosive force that drives the piston of a combustion engine

You will need....

- ✓ a few drops of octane
- ✓ large coffee jar (or 1 L flask)
- ✓ a card or beer mat with a small hole (1 cm diameter) to cover the flask

Background:

The average small car has an internal combustion engine of 1 L or a little more. Here we recreate it and show that the mixture ratio of octane to air is very important.



Follow these steps:

1. Put a few drops of octane into the covered jar and allow a few seconds for it to evaporate before dropping in a match.
2. The beer mat flips up with a satisfying whoosh!
3. Ask the students to predict what will happen if larger amounts of octane are used.
4. Try different amounts of octane and record the results. What is the ideal amount?

So what happened?

Combustion requires oxygen. When there is too much octane in the flask its vapour drives all the air (and oxygen) from the combustion chamber. Without the oxygen the octane vapour will not ignite.

What next?

1. Find the mass of a drop of octane and hence the mass of octane that is used in the 'best' mixture. Calculate the amount of oxygen required to burn this amount of octane and hence the amount of air required. Is the answer close to the volume of the jar?

Leaky test tubes

A model of chemical equilibrium

You will need....

✓ Two test tubes, one wider than the other.

✓ A rubber stopper with a hole, for each test tube.

✓ Two identical beakers one labelled ‘reactants’ and the other ‘products’.

✓ Water

✓ pointed metal rod

Background:

When equilibrium is reached there is no further change in proportion of reactants to products.

Safety

! Wear safety glasses when making the holes in the test tubes.

Follow these steps:

1. Make holes in the bottom of the test tubes by heating and gently pushing a pointed metal rod through the glass.
2. Pour some water into the ‘reactants’ beaker and leave the ‘products’ beaker empty.
3. Place the wider test tube (A) into the ‘reactants’ beaker and the other test tube (B) into the ‘products beaker.
4. Fit the rubber stoppers in the test tubes.
5. Place a finger over the hole in each rubber stopper and swap the test tubes. This will allow liquid to be picked up and transferred from one beaker to another.
6. Do this with both test tubes at the same time.
7. Slowly lift the test tubes and return them to the starting position without putting a finger over the holes in the stoppers.
8. Repeat steps 5 to 7 several times. An equilibrium position is reached.

So what happened?

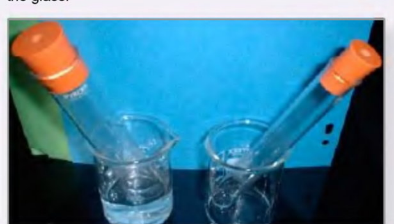
The liquid that is picked up in the wider test tube represents the forward reaction while that in the narrow tube is the back reaction.

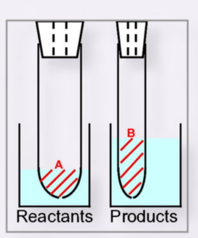
Initially the volume of A is greater than the volume of B and so there is a net transfer of liquid into the products beaker.

After a number of switches the level of liquid in the products beaker rises above the level in the reactants and the same volume of liquid is transferred in both directions. The total volume in each beaker represents the proportion of reactants and products.

What next?

This set up shows the equilibrium lying with the products. What about a reaction in which the equilibrium lies with the reactants?





Chemistry

Phoenix snake

Combustion and decomposition

You will need....

- ✓ Ethanol (10 ml)
- ✓ Sugar (2 spatulas)
- ✓ Wood ash (5 spatulas)
- ✓ Sodium hydrogen carbonate powder – baking soda (2 spatulas)
- ✓ Porcelain basin

Background:

This is a spectacular demonstration showing an ash snake rising out of the mixture, after several minutes.

Follow these steps:

1. Put the dry ash in the porcelain basin.
2. Add the sugar and sodium hydrogen carbonate powder.
3. Gently mix together in the centre of the basin.
4. Pour the ethanol around the perimeter of the mixture and ignite it with a splint.
5. Wait and observe.

So what happened?

The heat of the combustion causes the sodium hydrogen carbonate to decompose giving off carbon dioxide gas and it also causes the sugar to caramelise. The sticky mixture of the caramel and the ash is forced upwards by the carbon dioxide gas resulting in a spectacular 'phoenix snake'.

What next?

Write a reaction for the thermal decomposition of the sodium hydrogen carbonate.



Milk powder fire clouds

The effect of surface area on reaction rate

You will need....

- ✓ Milk powder
- ✓ Metre stick
- ✓ Splints
- ✓ 2 retort stands and clamps
- ✓ Bunsen burner
- ✓ Heat-proof mat

Background:

The spectacular demonstration uses dried milk powder which contains carbohydrates and fats that release energy on combustion.

Follow these steps:

1. Arrange 3 heaped spatulas of the dried milk powder into a small pile on a heat proof mat. Try to ignite this using a Bunsen burner.
2. Take a meter stick and fix a splint to one end. Arrange it so that the splint can burn freely above the heat-proof mat. This is important as the falling milk powder will not extinguish the flame as would happen with a candle.
3. From above, sprinkle the powder over the lit splint. The height of the sprinkle will dictate the height of the fire ball produced. Take care to stand back.

Safety

! Ensure that this can be carried out in compliance with the school's safety procedures.

So what happened?

The small pile burns slowly because the effective surface area is small, and so the reaction is slow.

When the same powder is sprinkled the reaction is much faster because the surface area is much greater.

If you are feeling brave, you could sprinkle the milk powder from a greater height.

What next?

1. Finely divided solids react more quickly than the larger pieces. This can be investigated using marble chips and acid on a top pan balance.
2. A safer alternative is to blow a fine powder over a candle flame in a large metal sweet can and watch the lid blow off.



Chemistry

Rainbow milkshake

pH spectrum from acid to base

You will need....

✓ Milk of Magnesia (20 ml)
✓ Vinegar (30 ml)
✓ Universal indicator

Background:

The reaction of milk of magnesia with vinegar (and a drop of universal indicator) produces an impressive spectrum of colours.

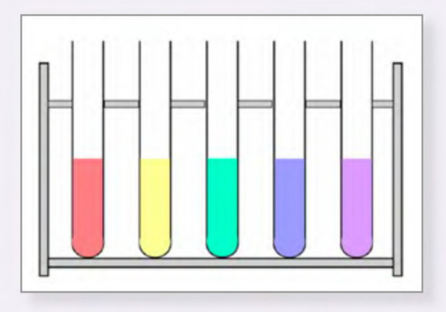
This demonstration shows the range of the pH scale using only one solution. It can also be used to discuss solubility.

Follow these steps:

1. Put the milk of magnesia in a small beaker. Adding a drop of universal indicator produces a strong basic colour.
2. Add the vinegar and swirl with a glass rod. Initially an acidic colour appears but is quickly replaced by another colour from the pH scale.
3. In turn each colour is replaced as the solution gradually becomes basic again.
4. This can be repeated a number of times and each time the colour changes occur more slowly until eventually there is an excess of acid and a permanent acidic colour.

So what happened?

Milk of Magnesia is a cloudy suspension due to un-dissolved particles. In the first moment of the reaction there is an excess of dissolved acid to dissolved base, producing an acidic colour. However the extra water added by the vinegar dissolves some of the suspended particles from the milk of magnesia. This takes a while and is assisted by swirling. The newly dissolved particles are basic and gradually increase the pH creating the slowly changing spectrum of colour that we see.



What next?

Students can dilute the milk of magnesia before adding the vinegar and see how this alters the colour produced.

A bleeding hand

Goldenrod paper used as an acid-base indicator

You will need....

- ✓ Solution of sodium carbonate - washing soda (2M)
- ✓ Goldenrod paper (Source: Flinn Scientific, Batavia, Illinois, www.flinnscientific.com)
- ✓ Paint brush

Background:

An alkali on Goldenrod paper turns the paper bright red. The effect lasts for several minutes.

Follow these steps:

1. Using the paint brush, paint the solution of the washing soda onto the hand of a volunteer.
2. Explain that this chemical will appear to draw 'blood' from the volunteer's hand.
3. Attach the goldenrod paper to a wall and ask the volunteer to slap their hand onto the Goldenrod paper.

So what happened?

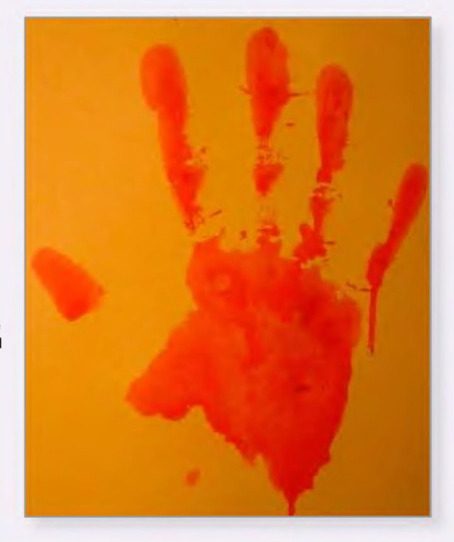
A deep red print of the hand is formed on the paper, with the 'blood' dripping down along it.

What next?

1. Discuss the pH scale and different types of indicators.

Safety

! Wash hands carefully after handling the sodium carbonate solution.



Chemistry

Salt and fizz

How much CO_2 is dissolved in a fizzy drink?

You will need....

- ✓ A glass
- ✓ Fizzy drink
- ✓ Salt
- ✓ Cloth to clean up

Background:

The demonstration verifies particle theory for dissolved gases.

Follow these steps:

1. Carefully pour the soft drink slowly down the edge of the glass to reduce fizzing.
2. Add the salt.
3. Watch what happens.

So what happened?

The drink fizzes up as the salt provides condensation sites for the CO_2 to form.

What next?

1. Try the experiment with other substances such as sugar or sand.
2. Investigate if the temperature of the drink affects the amount of gas evolved.



Steel wool sparkler

Iron is combustible

You will need....

- ✓ Steel wool
- ✓ 9V Battery
- ✓ Baking tray

Background:

The iron in the steel wool is finely divided and therefore it burns more readily than a block of iron.

Follow these steps:

1. Pull apart the steel wool until it is the size of a tennis ball.
2. Place the steel wool in the baking tray.
3. Touch the steel wool with the terminals of the battery.

So what happened?

Electric current heats some wires which ignite. A sparkling fire spreads through the loose ball of steel wool.

What next?

1. Even the Scouts manuals recommend starting a fire using this equipment rather than the traditional method of using a flint and steel.
2. This demonstration can be used to show how fuses work and the effect of current passing through thin wires.

Safety

! Care should be taken with naked flames.



Density

Racing candles

Convection in gases

You will need....

- ✓ 3 candles of different heights
- ✓ A large empty glass jar with an opening large enough to accommodate the three candles.

Background

When candles burn, oxygen is used up and carbon dioxide is produced as well as water vapour. The less dense products (hot carbon dioxide and water vapour) rise to the top of the glass jar.

Follow these steps:

1. Place the three candles near each other.
2. Light the candles, starting with the tallest one to avoid being burned.
3. Place a glass jar over the candles and observe.

So what happened?

The candle flames go out in order. The tallest goes out first, then the middle one and finally the smallest.

Since carbon dioxide does not support combustion the candles are extinguished from the top down. The water vapour that is formed condenses on the cold surfaces.

What next?

1. Discuss the use of carbon dioxide in fire extinguishers.
2. How can we show that the condensed liquid is water?
3. Discuss why people are advised to stay low in the event of fire.

Safety:

! Always take care with naked flames.



Take the Coke challenge

Sugar adds weight

You will need...

- ✓ Can of diet soft drink
- ✓ Can of regular soft drink
- ✓ Tank of water

Background:

Objects that are denser than water tend to sink while less dense objects tend to float. A sugar solution is denser than water.

Follow these steps:

1. Fill a tank with water
2. Lower the cans into the water
3. Observe

So what happened?

Both cans have the same shape and volume but the diet drink floats and the regular drink sinks.

This is because their densities are different.

What next?

1. Ask students why they think diet drink is less dense than regular version.
2. Investigate other factors that affect the densities of objects.
3. Is the orientation of the cans significant?



Density

Does air have mass?

Measure the density of air

You will need....

- ✓ three-litre plastic bottle
- ✓ syringe (e.g. 25 cm3)
- ✓ bicycle valve
- ✓ bicycle pump
- ✓ simple balance
- ✓ counter weight
- ✓ small piece of wood (3.6 g)
- ✓ punch or auger
- ✓ glue gun

Background:

When a gas is compressed to half its original volume its pressure doubles.

If the amount of air in a fixed volume is doubled the pressure is doubled.

Follow these steps:

1. Bore a hole in the cap of the bottle to hold the bicycle valve.
2. Seal the valve in the hole so that air can go in but not out.
3. Pull the plunger of the syringe to its full extent; measure the length of the air space and mark the middle with a permanent marker. Plug the nozzle of the syringe.
4. Put the syringe in the bottle and seal the bottle.
5. Hang the bottle on the balance and add a counter weight to the other side so that it is balanced.
6. Now remove the bottle and pump air in until the air in the syringe is reduced to half its original volume. Then replace the bottle on the balance.

So what happened?

The bottle is now heavier; balance can be restored by adding the 3.6 g piece of wood to the other side. This is the weight of three litres of air at normal temperature and pressure.

The density of air is therefore 1.2 g/L.





What next?

1. What is the mass of one litre of air? What is the mass of a cubic metre of air?
2. Measure the dimensions of the room and calculate the mass of air in the room.
3. The weight of a kilogram is about 9.8 N. The pressure of the atmosphere is 100,000 N/m^2. What mass of air is vertically above each square metre of the Earth's surface?
4. If the atmosphere were uniformly dense what height would it be?

A swinging candle

Inertia of Gases

You will need....

✓ lantern
✓ candle

Background:

Gases have mass and therefore inertia.

The air in the lantern is cooler and denser and has greater inertia than the hot gases in the flame. The denser air moves to the side of the lantern opposite to the direction of the acceleration.

Follow these steps:

1. Place a candle in a lantern.
2. Move it from side to side.

So what happened?

It appears at first that the flame moves in the direction of the movement. Closer inspection shows that in a draught-free container the flame moves in the direction of the acceleration. It the lantern starts from rest and moves to the right then the flame moves to the right until a steady speed is reached. At a steady horizontal velocity the flame is vertical. If the lantern is decelerated the flame moves in the opposite direction to the motion.

When a candle is burning in a draught-free room the flame rises vertically. In a stationary hanging lantern it would behave in the same way i.e. it would rise in the direction of the handle (force) that is holding it.

If the lantern were allowed to fall then neither the air nor the flame would experience any acceleration relative to the frame of reference (the lantern); there would be no convection and the flame would die for lack of oxygen.

Safety

! Care must always be taken when using lighters, matches, candles or naked flames of any kind.

What next?

1. Compare the motion of the flame to that of water and air (or water and oil) in a closed bottle.
2. In an open space investigate what happens if the lantern is swung in a horizontal or vertical circle.
3. View the following website: http://www.nasaexplores.com/show2_articlea.php?id=03-022



Density

Twinkle, twinkle, little laser

Recreate the shimmering light from distance stars and galaxies in the laboratory

You will need....

✓ Laser
✓ Candle
✓ Screen

Background:

A laser beam passes over a lighted candle and produces a twinkling spot on a distant screen.

Follow these steps:

1. Set up the laser so that its beam passes over the candle flame.
2. Observe the spot on the distant screen.
3. Gently blow the flame.
4. The spot will visibly move.

So what happened?

Why should laser light and candlelight seem to interfere?

Laser light travels in a straight line when travelling through a medium of uniform refractive index.

The heat from the flickering flame causes the density and the refractive index of the air to change and so the laser spot dances on the screen.

What next?

1. The demonstration describes clearly why stars twinkle. When you look at a star you are viewing it through the layers of the earth's atmosphere. These layers have different densities and are not stationary. This causes the starlight to fluctuate.



Underwater fireworks

Visual display of immiscible liquids

You will need....

- ✓ Large clear glass bowl
- ✓ Water
- ✓ 1 tablespoon vegetable oil
- ✓ Paper cup
- ✓ Food colouring-red, green, blue
- ✓ Spoon

Background:

Oil and water are immiscible-meaning they do not mix but separate into layers because of the different polarity of their molecules. The oil rises to the surface because it is less dense than the water. Since the water-based food colouring does not dissolve in oil, it remains in tiny spheres throughout the oil on the water's surface, then sinks through the oil layer and dissolves in the water below, creating long streamers of colour.

Follow these steps:

1. Fill the bowl with water.
2. Pour the oil into the paper cup.
3. Add a few drops of each food colouring colour.
4. Mix the oil and colours thoroughly with the spoon.
5. Pour the coloured oil mixture into the water in the bowl.
6. Observe for ten about minutes.

So what happened?

Small pools of oil spotted with spheres of colour float to the surface of the water, exploding outward and creating flat circles of colour on the surface of the water. Long streamers of colour then sink down though the water like a fireworks display.

What next?

Investigate other liquids to see are they miscible or immiscible.



Density

Your very own piece of a black hole

Refractive index of liquids

You will need....

- ✓ Small transparent tank
- ✓ Laser
- ✓ Salt
- ✓ Water
- ✓ Funnel and tubing
- ✓ Suitable exotic object

Background:

The speed of light varies with the density of materials.

Follow these steps:

1. Place the object at the bottom of the tank.
2. Half fill the tank with water.
3. Make up a saturated salt solution by adding salt to water until no more dissolves. (The salt dissolves more rapidly in warm water.)
4. Using the funnel and tubing carefully add the salty water underneath the water already in the tank.
5. Position the laser to produce the desired curving of light.

So what happened?

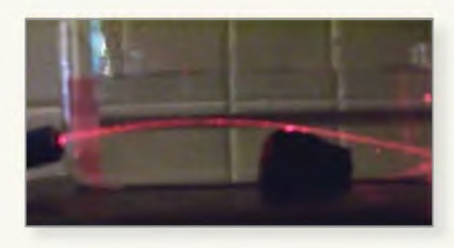
The gradual variation in the concentration of the salt solution results in gradual variation in the refractive index of the solution.

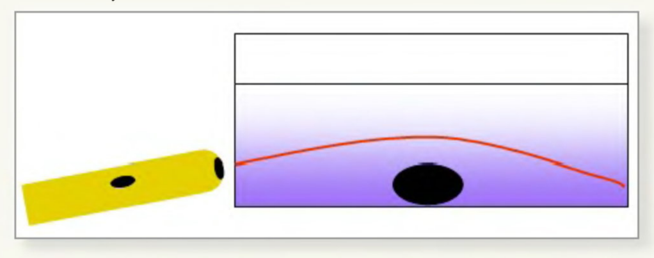
Thus the laser beam is gradually refracted and the light is curved downwards, giving the impression that the piece of black hole is bending the light.

What next?

This demonstration can be used to explain:

- Gravitational lensing
- Total internal reflection
- The principle of the mirage (inverted).





Bird on a Wire

Potential difference and current

You will need....

- ✓ battery (4.5 V is very suitable)
- ✓ LED
- ✓ 220 Ω resistor
- ✓ bare wire

Background:

Current flows in a circuit if there is a potential difference. The bird's eye can light only when the feet are at different potentials, e.g. when they straddle the road.

Follow these steps:

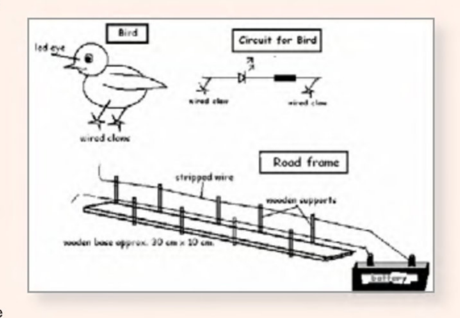
1. Make a 'road' as in the diagram. The wire used is single-core stripped telephone wire and is threaded though the wooden supports.
2. The bird is made of cardboard with the circuit pasted on the reverse side. The resistor should be added in series with the LED 'eye' and connected to the wired 'claws'.
3. By arranging the bird to 'sit' in different positions on the wire the LED will either light up or not

So what happened?

When the claws are both on the same strip of wire there is no potential difference between them and so the LED does not light up. However when the claws straddle the wires there is a potential difference and so the LED lights up.

What next?

1. This circuit can also be used to illustrate the forward/reverse nature of LEDs.
2. Using a 4 V AC supply the LED will light even if the bird's feet are reversed.



Electricity and magnetism

Charged rolling drink can

Electrostatics in motion

You will need....

✓ Aluminium drink cans
✓ Nylon rod or pocket comb
✓ Cotton cloth
✓ Scissors
✓ Tape

Background:

An empty drink will roll towards a charged object that is brought close to it.

Follow these steps:

1. Charge the rod rubbing it with the cloth.
2. Bring it close to the can.
3. If the force isn't great enough the ends of the can be cut off making it lighter.
4. Use tape to prevent cuts from sharp ends.

So what happened?

The can will roll toward the rod, attracted to it because of the opposite charge induced on it.

What next?

1. Try different combinations of materials; e.g. nylon rod and polyester cloth, perspex rod and polyester cloth, perspex rod and wool, glass rod and silk etc.
2. Does a conductive roller work better than a non-conductive one?
3. Is the effect better when carried out on a conductive surface or on a non-conductive one?
4. What difference does it make if the objects/ materials are dried with a hair-dryer?



Easy electrostatics

Induced and contact charges

You will need....

- ✓ 1 audio cassette box
- ✓ Tissue paper
- ✓ Cloth

Background

Charge can be distributed unevenly on a neutral object.

Follow these steps:

1. Tear the tissue paper into tiny pieces – the smaller the better.
2. Put the pieces in to the cassette box and close it.
3. Rub the top surface of the box with the cloth.

So what happened?

The pieces will be attracted to the top. As you rub the box with the cloth electric charge is transferred from one to the other.

The pieces of paper are attracted to the charge on the top of the box.

What next?

1. A charged rod can be brought close to the top of the box-notice what happens.
2. What happens to the paper if a person touches the box?
3. What is the effect of placing the cassette box on an earthed conductive surface?



Electricity and magnetism

Charged rod and finger

Electrostatic force

You will need....

- ✓ a clock glass
- ✓ a non-conducting rod e.g. a plastic ruler
- ✓ a wooden ruler (metre stick)
- ✓ Van de Graaff generator
- ✓ cloth

So what happened?

The rod follows your finger around. The charged object induces a redistribution of electric charge on nearby objects, repelling similar charges and attracting opposite charges.

What next?

1. Investigate the electrostatic effects produced when using other materials and different combinations of charged and uncharged objects.

Background:

A charged object will be attracted to a neutral object causing a redistribution of electric charge.

Follow these steps:

1. Charge the rod using the cloth and balance it on the clock glass. Bring your finger close to one end of the rod (not the end you were holding when you were charging it) (Photo 1).
2. Next, balance the wooden ruler on the clock glass. Charge the plastic rod and bring it near the wooden ruler (Photo 2).
3. Then balance the wooden ruler on the clock glass. Charge yourself using a Van de Graaff generator. As you bring your finger near the ruler the force of attraction will cause the rod to move (Photo 3).



Photo 1



Photo 2



Photo 3

Magnetic needle

Magnetic effect of an electric current

You will need....

- ✓ a battery and switch
- ✓ needle and thread
- ✓ about 3 m of single-core wire (e.g. telephone wire)
- ✓ a circular former (card or plastic tube, 5 – 10 cm in diameter)
- ✓ a piece of wood or stiff card as a base.

Background:

An electric current in a solenoid produces a magnetic field within and around the solenoid; this field affects a needle suspended within the solenoid.

Follow these steps:

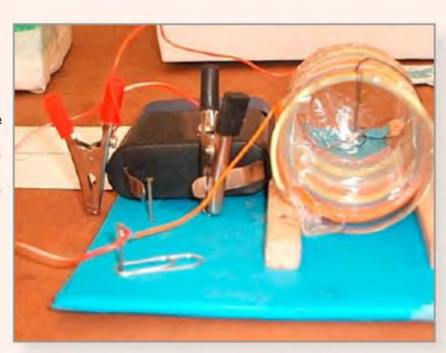
1. Make a solenoid by wrapping about 20 turns of wire around a circular former (e.g. a section of a plastic bottle) and leave about 10 cm of the wire free at each end. Secure the wire in place using adhesive tape. Attach the solenoid to the base.
2. Suspend the needle within the solenoid by means of a piece of thread.
3. Connect the battery and the switch in series with the solenoid. Wait until the needle is steady. Then close the switch and observe the movement of the needle. Open the switch and again observe the needle. Reverse the battery connections and repeat the procedure noting again the behaviour of the needle each time.

So what happened?

When the switch is closed a magnetic field is set up within and around the solenoid and the needle is deflected towards the axis of the solenoid.

What next?

1. Use a Hall probe to measure the magnetic flux density.
2. Explore how the flux density varies with the current.
3. Explore how the flux density varies with the number of turns.
4. Make a few solenoids of different diameters and explore how the flux density varies with the diameter.



Electricity and magnetism

Magnetic brakes

Induced current opposes the change which causes it

You will need....

- ✓ a toy car
- ✓ an aluminium or copper runway
- ✓ a timber or plastic runway
- ✓ neodymium magnets
- ✓ adhesive tape

Background:

The induced current opposes the change that causes it. This is expressed formally in Lenz's Law.

Follow these steps:

1. Stick the magnets to the underside of the car using adhesive tape, making sure that car can still roll freely.
2. Tilt the aluminium and timber runways equally.
3. Place the car on the aluminium runway and observe its motion.
4. Place the car on the timber runway and observe its motion.

So what happened?

The car moves much more slowly down the aluminium runway. As the car moves, the magnets induce eddy currents in the aluminium but not in the wood. The magnetic field resulting from the eddy currents opposes the motion of the magnets (and car).

What next?

1. Compare the effect of having all the magnets oriented the same to having them arranged N, S, N, S....



An even simpler motor

The force on a conductor in a magnetic field

You will need....

- ✓ 1.5 V cell
- ✓ Steel screw
- ✓ Neodymium magnet
- ✓ Piece of wire

Background:

A current carrying conductor experiences a force in a magnetic field.

Force = *BIL*
where *B* is the magnetic flux density, *I* is the current and *L* is the length of conductor within the field (Lorentz Force Law)

Follow these steps:

1. Place the screw between the magnet and the negative terminal of the cell.
2. Connect one end of the wire to the positive terminal of the cell.
3. Complete the circuit by brushing the other end of the wire against the magnet.
4. Observe what happens.

Safety note

! The circuit as described has little resistance and the electric current may be large.

! It is therefore not advisable to use batteries with low internal resistance such as or NiMH.

So what happened?

The screw and magnet rotate.

In this instance the magnet is part of the electric circuit. The horizontal current from the edge to the centre is in a vertical magnetic field and experiences a force perpendicular to both.

What next?

1. Invert the magnet and repeat.
2. Invert the battery and repeat.
3. Insert a lamp (1.5 – 2.5 V, 0.5 – 1.0 A) on the connecting wire.



Electricity and magnetism

Runaway Magnets

The force on a conductor in a magnetic field

You will need....

- ✓ 6 V battery
- ✓ 2 strips of aluminium foil
- ✓ Two neodymium disc magnets
- ✓ Steel axle (e.g. cut the head and point off a steel nail)
- ✓ adhesive tape

Background:

A current carrying conductor experiences a force in a magnetic field.

Force = BIL

(Lorentz Force Law)

Follow these steps:

1. Stick the two aluminium strips to the table top with adhesive tape (on the ends).
2. Connect the battery to the aluminium strips.
3. Attach the two magnets to the ends of the axle as wheels; similar poles should face one another.
4. Place the 'wheels' on the aluminium strips.

So what happened?

The 'wheels' roll along the aluminium strips.

In this instance the magnets are part of the electric circuit. A vertical current from the track to the axle is in a horizontal magnetic field and experiences a force perpendicular to both, i.e. in the direction of the track.

If similar poles are facing one another then the upward current on one side and the downward current on the other side experience a force in the same direction.

What next?

1. Change the polarity of the aluminium strips and repeat.
2. Change the polarity of one of the magnets and observe what happens.



Quick circuit boards

A versatile assembly for investigating electric circuits

You will need...

- ✓ board (preferably covered in white melamine) 12 cm × 15 cm
- ✓ 4 nails (4 cm)
- ✓ 4 paper clips
- ✓ 4 drawing pins
- ✓ insulated wire
- ✓ soldering facility

Background:

This apparatus was developed to enable students to assemble, investigate and modify electric circuits quickly and easily. The boards are stackable and durable. (The ones shown here have been in use for over twenty years.)

Follow these steps:

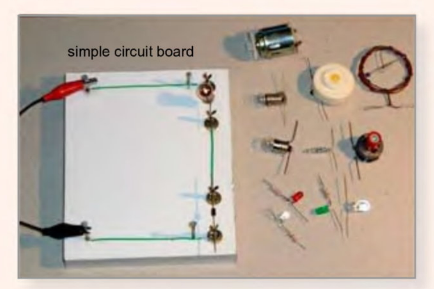
1. The measurements are not critical. The pairs of paper clips are used to hold circuit components temporarily in place. A suitable gap is 3 cm.
2. The drawing pins are inserted into the board and the heads of the paper clips are the soldered to the heads of the drawing pins. This can be tricky and requires three hands. For best results, and for ease of assembly, the heads of the pins and clips should be tinned with solder in advance.
3. Some components will need to have short wires added to them so that they can be easily inserted.
4. The two extra nails facilitate stacking.

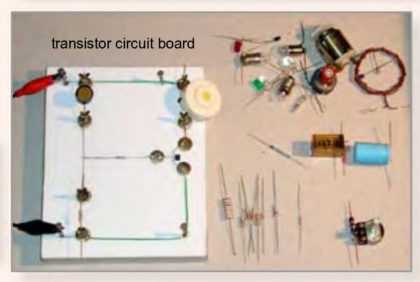
So what happened?

A great variety of series circuits can be assembled using one board. It is best to use a pair of boards when investigating parallel circuits.

What next?

1. A useful transistor version can be assembled in a similar way; this requires nine drawing pins and six paper clips. A suitable NPN transistor is ZTX300; use a 2k2 resistor on its base.
2. Make permanent versions of the more important demonstration circuits.





Electricity and magnetism

The circuit map

Introduction to electric circuits

You will need....

- ✓ A3 laminated copies of the circuit map
- ✓ Circuit components: battery, wires/leads, light bulb, ammeter, diode etc.

Background:

Students often find it difficult to relate assembled circuits to conventional circuit diagrams.

Follow these steps:

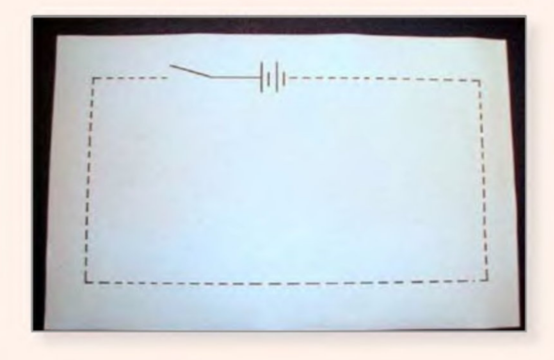
1. Each student is given a circuit map and a variety of components.
2. The battery and switch are placed on the appropriate symbol.
3. The other components are spaced out along the dotted line.
4. Finally each component is connected to the next using wires.

So what happened?

Because the Circuit Map is a regular shape students become more confident in interpreting circuit diagrams and building them.

What next?

1. A Circuit Map can be devised to help students build parallel circuits.
2. The Circuit Map can be adapted for use with transistor circuits.



Faraday torch

Generating atlernating current using magnets on a spring

You will need...

- ✓ One coil with 10,000 windings
- ✓ 2 springs
- ✓ 2 nuts
- ✓ 10 small neodymium magnets
- ✓ 1 retort stand
- ✓ 3 clamps
- ✓ 1 bridge rectifier using two red and two green LEDs

Background:

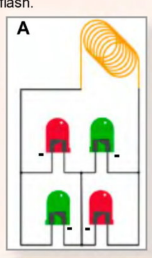
Moving a magnet repeatedly through a coil generates an electric potential. Shaking a Faraday Torch operates on this principle.

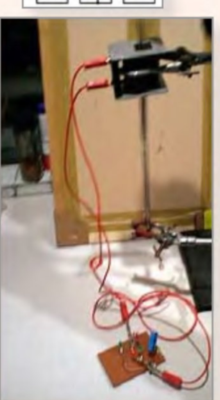
Follow these steps:

1. Attach clamps to the top, middle and bottom of the stand. Attach the coil to the middle clamp.
2. Connect the magnets between the two springs.
3. Attach one spring to the top clamp and pass the other end through the coil and attach it to the bottom clamp.
4. Adjust the position of the coil so that the magnets are at its centre.
5. Connect two leads between the output of the coil and the bridge rectifier circuit (A).
6. Set the magnets oscillating.

So what happened?

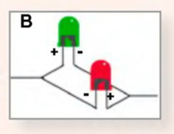
Pairs of LEDs flash alternately. The column of magnets vibrating up and down creates a changing magnetic field threading the coil; this generates an alternating current which causes the LEDs to flash.

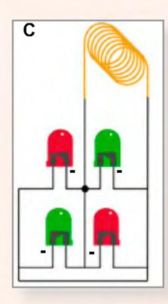




What next?

1. Video the flashing and play back in slow motion to view the sequence of flashing of LEDs.
2. Connect the output from the coil to an oscilloscope or laptop with data logger software to view the wave form and to measure the value of the output voltage.
3. Below are two alternative circuits (B & C); these will light at a lower voltage than the bridge arrangement (1.5 V vs. 3 V).





Electricity and magnetism

Action and reaction

The opposing movements of blood and body

You will need....

- ✓ a trolley or platform on which a person can lie; it must be free to move
- ✓ neodymium magnet
- ✓ coil into which the magnet can easily fit
- ✓ computer

(The 'trolley' shown here consisted of a sheet of wood (ca. 2 m × 0.5 m) resting on two lengths of PVC pipe.)

Background:

The human body moves as a reaction to the movement of blood in the aorta. When the left ventricle contracts of the blood is pumped through the aorta. Some goes towards the head but most goes towards the feet. The reaction is that the body moves in the opposite direction.

Follow these steps:

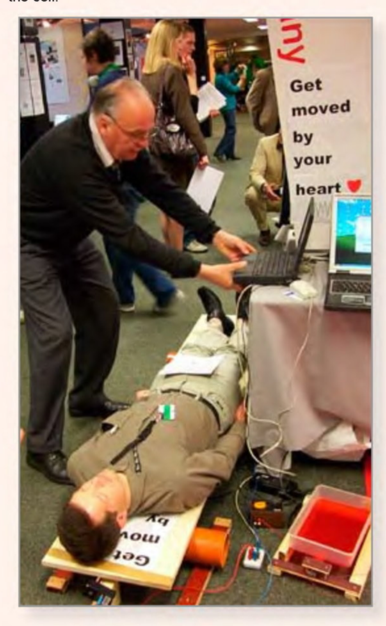
1. Attach a neodymium magnet to one end of the trolley or moveable platform. Fix the coil so that the magnet can move in and out of it freely. Attach the leads from the coil to the microphone input of a computer. Any audio capture software can be used to monitor and record the input (e.g. Audacity).
2. If a person is lying on a trolley then it will be found to move slightly with each heartbeat. The corresponding signals can be recorded on the computer.

So what happened?

The movement of the magnet in and out of the coil induces a varying electric potential in the coil.

What next?

1. How can this system be adapted to work with a chair or armchair?
2. Could such a system be modified for use in a hospital to monitor a patient's heartbeat without the necessity to attach wires to them?



The Earth generator

Use the Earth's magnetic field to generate electricity

You will need....

- ✓ A coil with 10000 turns
- ✓ A computer with Audacity (free download from http://audacity.sourceforge.net/)
- ✓ Cable with 3.5 mm plug (made from old headphones)

Background:

At the Earth's surface the intensity of the magnetic field varies from 25 μT (microtesla) to 65 μT. Even though this is very small, a rotating coil cutting the earth's field lines can generate a small voltage in the coil.

Follow these steps:

1. Connect the coil to the headphone cable and plug it into the microphone socket. The sensitivity can be adjusted in the software and the recorded signal can be amplified afterwards.
2. Whirl the coil over your head. Because of the angle of dip of the earth's magnetic field, face North and vary the angle of the plane of rotation to achieve maximum effect.
3. For safety purposes use a washing tablet net to prevent the coil detaching from leads.

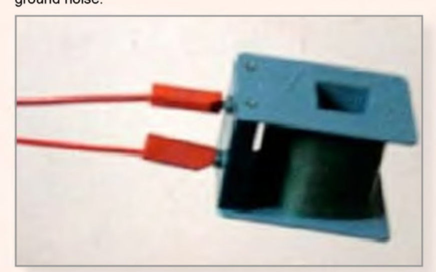
So what happened?

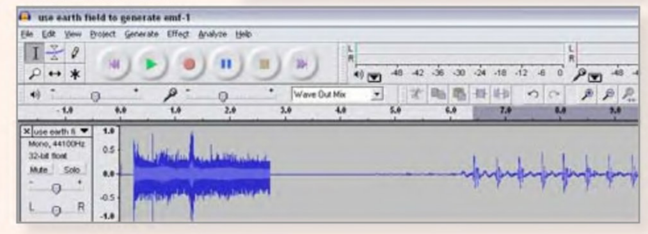
The first section of the graph is the recorded signal when the coil was stationary for about three seconds. It shows non-periodic background noise.

The next section shows the signal from the rotated coil unamplified and then amplified. Its frequency is that of the rotation.

What next?

1. What effect do you get if you let the coil hang vertically and spin it clockwise or anti clockwise.
2. Find out if an orbiting satellite can generate its power by a trailing cable cutting the earth's magnetic field.





Electricity and magnetism

iPod pickup

Energy conversions

You will need...

- ✓ iPod or minidisk player
- ✓ Walkman (cassette player)
- ✓ Earphones or headphones
- ✓ External speaker
- ✓ Solenoid (e.g. 30 turns)

Background:

A cassette player can detect changing magnetic fields which are then amplified.

Follow these steps:

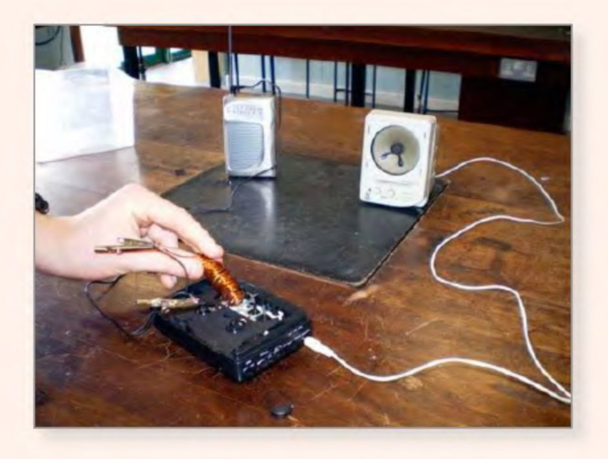
1. Remove the earphones keeping the lead and plug. Connect the wires of the lead to the ends of the solenoid and insert the plug into the output of the iPod. Play some music on the iPod.
2. Set the Walkman to 'Play' (without a cassette) and attach the external speaker to its output or headphone socket.
3. Move the solenoid around over the central part of the Walkman.

So what happened?

Music from the iPod is heard on the external speaker, depending on the location of the solenoid.

What next?

1. List all the energy conversions involved in this demonstration.



A two-part ammeter

Make a simple functional ammeter

You will need....

- ✓ Magnetic plotting compass
- ✓ Enamelled copper wire
- ✓ Plastic or paper former
- ✓ Two pins
- ✓ Card or wood base (ca. 80 × 80 mm)
- ✓ (Variable power supply and multimeter for calibration)

Background:

The current in the coil produces a magnetic field which can deflect a compass.

Follow these steps:

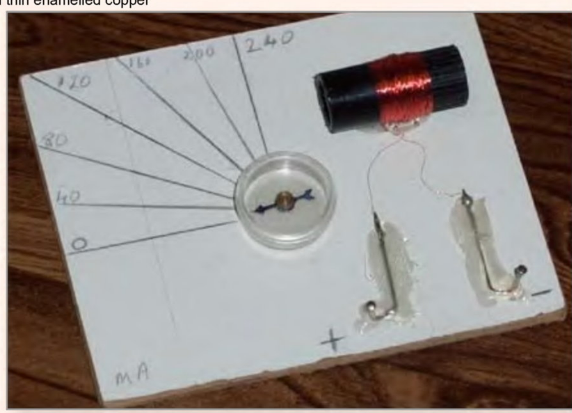
1. Make a solenoid by winding about 50 turns of thin enamelled copper wire around a plastic or paper former. Remove the enamel from the ends of the wire and solder them to two pins.
2. Glue the solenoid, pins and compass to the base with hot glue; arrange as shown in the picture.
3. Calibration: Orient the assembly so that the compass needle is parallel to the axis of the coil; mark this as zero. Attach a power supply so that a current deflects the compass needle clockwise. Increase the current in the coil in steps of 40 mA (or other suitable value). Mark the position of the compass needle at each step.

So what happened?

The solenoid acts as a magnet when there is an electric current in the wire. The magnetic field of the solenoid deflects the compass needle. This 'meter' works quite well; its disadvantage is that it must be aligned in a South-North direction.

What next?

1. Make meters for different current ranges. Use heavier wire and fewer turns for larger currents.



Electricity and magnetism

Printing magnetic fields

A convenient way to plot magnetic fields

You will need....

- ✓ iron filings
- ✓ bar magnets
- ✓ a photocopier

Background:

Iron filings line up along the lines of force of a magnetic field.

Follow these steps:

1. Sprinkle iron filings evenly on the glass of a photocopier. Place magnets gently on the glass. Tap the edge of the glass a few times until the filings form a distinct pattern.
2. Close the cover. Photocopy.

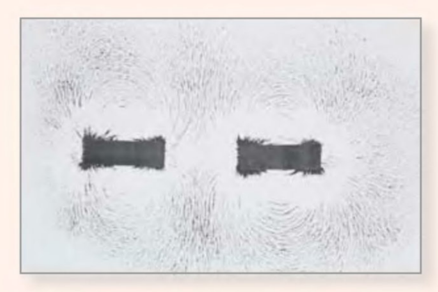
So what happened?

The iron filings in the space near the magnet (the magnetic field) become magnetised particularly those that are near their poles and attract one another. As a result they tend to form lines.

If the iron filings are not evenly spread at the start then the magnetic field may appear asymmetric.

What next?

1. Add small plotting compasses and photocopy the results.
2. Instead of placing the magnets directly on the photocopier glass, raise them one or two centimetres by means of small blocks of wood or plastic – preferably of the same horizontal dimensions as the magnets.
3. Investigate the effect of placing some metallic objects on the glass before sprinkling on the iron filings; use ferro-magnetic and non-magnetic objects, e.g. a steel nail, a nickel coin, a copper coin, a paper clip, a key etc.





Paper speaker

Force between a magnet and an electromagnet

You will need....

- ✓ A piece of card
- ✓ Thin enamelled copper wire
- ✓ A strong magnet (e.g. neodymium)
- ✓ Adhesive tape
- ✓ Audio cable with 3.5 mm plug

Background:

A typical audio speaker is composed of a diaphragm (usually a paper cone), a coil of wire attached to the diaphragm and a separate magnet which is placed near or around the coil.

Follow these steps:

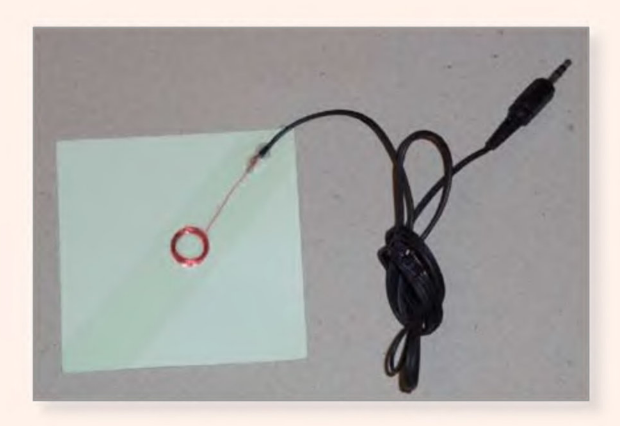
1. Wind about 30 turns of the enamelled copper wire around a pen or small smooth cylinder.
2. Secure the ends (by twisting). Stick the coil to the centre of the card using adhesive tape.
3. Remove the enamel coating from the last two centimetres of the ends of the wire. Connect the wires in the audio lead to the ends of the coil by twisting or soldering.
4. Stick the lead to the card with more adhesive tape.

So what happened?

If the lead is attached to an audio signal source (a headphone socket on a radio or tape player) no sound can be heard from the card until the magnet is bought near it.

What next?

1. Investigate how the sound can be enhanced (using cups, cylinders, boxes etc.).
2. Can the device act as a microphone (generate electricity when exposed to sound)?



Electricity and magnetism

Using a speaker as a microphone

Changing magnetic field induces a voltage

You will need:-

- ✓ 1 laptop with Audacity (free download from http://audacity.sourceforge.net/)
- ✓ 1 speaker with leads
- ✓ 1 jack plug (3.5 mm) with leads

Background:

A visual display of waveforms helps students understand the wave nature of sound.

Follow these steps:

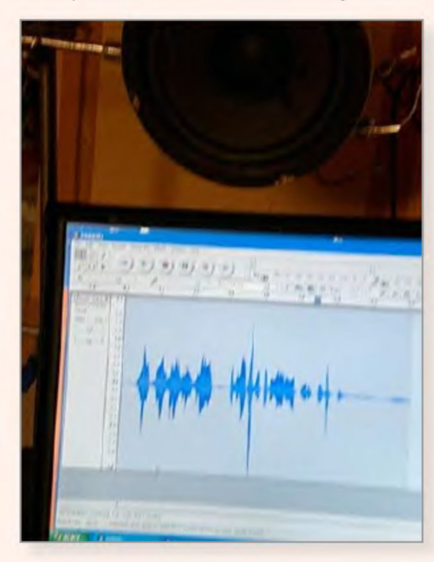
1. Connect the speaker to the earphone jack and insert it into microphone jack in laptop.
2. Place the speaker (now acting as a microphone) on the bench.
3. Run Audacity.
4. Ask a student to talk into the speaker. Press the Record symbol and observe the pattern on the screen.
5. Press the Stop symbol on screen and highlight part of the wave.
6. Go to Effect on tool bar and select Amplify, move slider to right (you may have to unclick clipping option).
7. Play back the recorded signal.
8. Select Effect again and try other options such as Change Pitch and play again. This is both enjoyable and instructive.

So what happened?

A speaker can operate as a microphone, because when you talk into the speaker the sound causes the speaker cone to vibrate. The speaker is attached to coil in a magnetic field; when this vibrates an alternating voltage is induced in the coil. When it is connected to the microphone input of the computer the signal can be monitored.

What next?

1. You can also grab digitised music from various sources or do voice-overs.
2. Audacity can be used as a 'recording studio' and can produce many interesting and entertaining effects.



Thermoelectricity

Seebeck effect

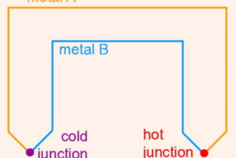
You will need....

- ✓ Strip of aluminium (4 cm x 20 cm)
- ✓ Strip of copper (4 cm x 28 cm)
- ✓ 2 bolts
- ✓ Magnetic compass
- ✓ Container of melting ice
- ✓ Container of boiling water
- ✓ Sandpaper

Background:

A thermoelectric loop consists of two strips of dissimilar metals that are connected together at two junctions. If the junctions are at different temperatures an electric current will pass through the resulting loop, indicating the presence of a potential difference. This effect was discovered in 1821 by Thomas Johann Seebeck (1780-1831). In 1834 the reverse effect was discovered by Jean Peltier.

Thermoelectric voltages are typically a few millivolts per kelvin. If the conductors are large (as in this case) the currents can be many amperes.



Follow these steps:

1. Bend the strip of aluminium at both ends by 90º.
2. Bend the strip of copper at both ends by 90º and also in the centre bend a square hoop shape.
3. Clean the contacting surfaces of the aluminium and copper with the sandpaper and join them together using a bolt at each end.
4. Place the compass in the open loop.
5. Place one junction into the ice cold water and the other junction into boiling water and observe the compass needle turn by 45 º.
6. Exchange the containers and the needle turns back about 90º.

So what happened?

The thermoelectric junctions produced an emf (potential difference) and an electric current flows in the loop. The resulting magnetic field deflects the compass needle to point in the direction of the vector sum of this field and the horizontal component of the magnetic field of the earth.

What next?

1. Investigate how the direction of the flow of current depends on the location of the hot and cold junction.
2. Place the compass on top of the loop.
3. Investigate the magnetisation of a soft iron core inside the loop.



Forces

Five buttons and gravity

Measurement of the acceleration due to gravity

You will need....

- ✓ five buttons or washers, all the same size and mass
- ✓ a piece of white thread (50 cm)
- ✓ a short length of glass tubing with smooth edges (6 cm long)

Background:

The weight of four buttons/washers provides the centripetal force required to maintain one button/washer in circular motion.

Follow these steps:

1. Ensure that the ends of the glass tube are very smooth.
2. Put the thread through the glass tube. Tie one button to one end and four to the other end of the thread. Mark the thread at a point 25 cm from the centre of the single button.
3. Holding the glass tube vertically, move it in a circular motion so that the single button moves around in a circle of radius about 25 cm. By varying the rate of rotation the radius of the orbit can be increased or decreased. Vary it until the 25 cm mark is exactly at the top of the glass tube and maintain a steady speed. Time 50 or 100 revolutions and calculate the time for one revolution (T).

So what happened?

The centripetal force is provided by the weight of the four buttons:

$$mr\omega^2 = 4\,mg$$

and

$$\omega = 2\pi / T$$

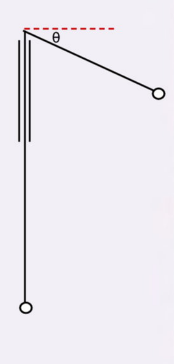
so

$$r\,(2\,\pi / T)^2 = 4g$$

or $$g = r\,\pi^2 / T^2$$

If r = 25 cm then

$$g = 2.47 / T^2$$



What next?

1. The thread holding the button in orbit is not exactly horizontal; the angular dip depends on the motion. If the declination is θ then the radius of the orbit is not r but $r\cos\theta$.
2. Because of the declination the centripetal force is reduced from $4mg$ to $4mg\cos\theta$. The forces are now described by the equation: $mr\cos\theta.\omega^2 = 4mg.\cos\theta$ Since $\cos\theta$ is the same on both sides, the equation is essentially the same as the first equation above.



A Newtonian Fan

Demonstrating Newton's Third Law

You will need....

✓ A battery operated fan

Background:

According to Newton's Third Law, to every action there is an equal and opposite reaction.

Follow these steps:

1. Place the fan vertically on the table so that it is free standing.
2. Switch it on, and observe the motion of the body of the fan.

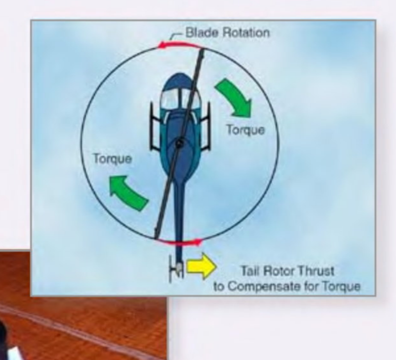
So what happened?

As the horizontal blades rotate the body of the fan rotates in the opposite direction!

What next?

This can be extended to study the role played by the main horizontal rotor and the vertical rotor blades of a helicopter when flying, hovering or turning.

(Image from Wikipedia)



Forces

Uplifting forces

Demonstrating Bernoulli's principle with a liquid

You will need....

- ✓ A funnel
- ✓ A length of tubing
- ✓ A table tennis ball

Background:

Bernoulli's Principle explains the uplift due to velocity and pressure differences.

Follow these steps:

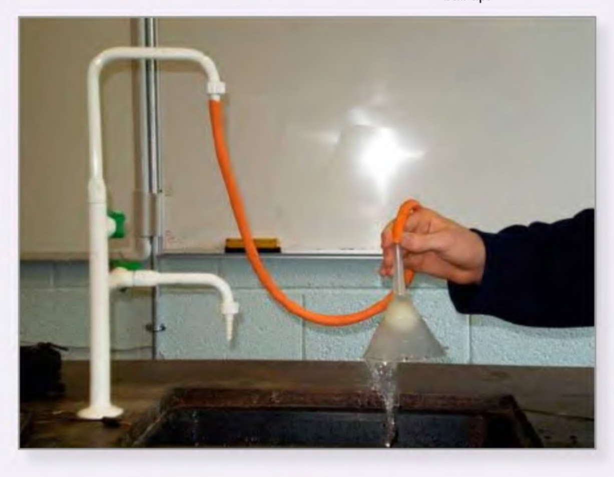
1. Connect a tap to the funnel using some rubber tubing.
2. Hold the funnel upside down and hold the table tennis ball up against the opening.
3. Turn on the water and let go of the ball

So what happened?

The ball stays up in the funnel instead of falling down because the pressure above is less than the pressure below it, due to the water going around the ball.

What next?

1. Try blowing into the upside down funnel and see if how long you can keep the ball up.



Boomerang Ball

A counterintuitive exercise in spin and friction

You will need....

✓ A bouncy ball
✓ A table or similar

Background:

The spin of a ball dictates the direction of the bounce.

Follow these steps:

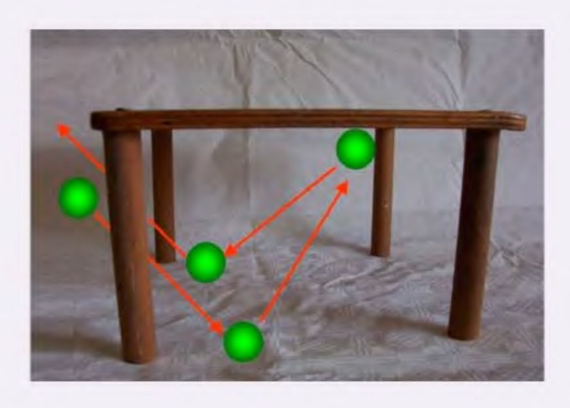
1. Pose the question “what will happen the ball as it is bounced downwards under the table?” Most people will assume that the ball will bounce under and though the table
2. Try bouncing the ball.

So what happened?

Due to friction the ball starts to spin forward when it strikes the lower surface. When it strikes the upper surface this becomes a back-spin and causes the direction of the ball to change. As a result the ball returns towards the starting position.

What next?

1. How can we force the ball to bounce through? A back spin can be applied on the ball at the first bounce. This results in a forward spin at the upper surface, so the ball will bounce through.
2. Alternatively if the ball is wet, the friction is reduced and the ball will bounce though.
3. For videos and animations see Dr Hugh Hunt’s website at http://www2.eng.cam.ac.uk/~hemh/movies.htm



Forces

Brainy ball

Free fall acceleration seemingly greater than *g*

You will need....

- ✓ a drill or punch
- ✓ 2 wood screws
- ✓ 2 clean, empty tins (or other suitable containers)
- ✓ 1 piece of wood one metre long (e.g. a metre stick or preferably something heavier)
- ✓ 1 ball (preferably one that does not bounce much)

Background:

Gravity accelerates all objects to the earth at the same rate.

Follow these steps:

1. Drill a hole in the bottom of each container.
2. Attach the containers to the stick at the 95 and 82 cm marks.
3. Place the stick on the floor, perpendicular to a wall, and move the free end against the wall.
4. Place the ball in the can nearest the other end and lift that end 50 cm from the floor.
5. Let it drop to the floor.

So what happened?

When the stick falls to the floor, the ball in the first can falls into the second can.

You would expect that the ball would stay in the first can.

When the stick (plus its attachments) is released its centre of gravity accelerates downward at approximately g. Because the lower end cannot move downwards the upper end must be accelerating at a rate greater than g – almost 2 g if the 'cans' are very light. The ball, which is not attached to anything, accelerates at g, i.e. more slowly than the upper end of the stick.

What next?

1. Calculate the correct positions for the containers for other release heights.
2. Calculate the correct positions of the containers for other lengths of the wood.



Bubbles in free fall

Spherical bubbles have minimum surface area

You will need....

✓ A clear plastic bottle nearly full of water

Background:

Astronauts often demonstrate the formation of free floating spheres of water in the ISS (International Space Station). Air in water bottles similarly forms spherical bubbles.

The ISS is not actually in zero gravity; in fact the acceleration due to gravity at that height (300 to 400 km) is about 90% of its value on the Earth's surface.

However, because the ISS and its contents are all in free-fall it seems to those inside it that there is no gravity. It is the gravitational force between the Earth and the ISS that keeps it from flying off into space.

Follow these steps:

1. Throw the bottle upwards and observe what happens to the air inside it.

So what happened?

The air very quickly forms large free-floating spherical bubbles while the bottle is in 'free fall' – on the way up and on the way down. The surface area of the bubble is a minimum when it is a sphere.

What next?

1. Attach a bottle of water and a mini surveillance camera/transmitter to a ruler and drop the whole assembly from a height to someone with a good catch! Record and analyse the results.



Forces

The climbing playing card

An intriguing example of sliding friction

You will need....

- ✓ a stiff card ~ playing card size
- ✓ a drinking straw
- ✓ adhesive tape
- ✓ a piece of wood (e.g. a lollipop stick)
- ✓ 2 washers or small weights
- ✓ 3 pieces of string; 2 × 1 m and 1 × 50 cm each



Fig. 1

Background:

Friction is a force between two surfaces that are in contact. It inhibits relative motion (sliding) of the surfaces. The size of the force depends on the nature of the materials involved and on the force with which they are pressed together. It generally does not vary with the area of contact.

There are three basic types of friction – static, sliding and rolling friction.

The Climbing Card is a neat demonstration of both static and sliding friction.

Follow these steps:

1. Cut two 5 cm lengths from the straw and fix them to the card with adhesive tape as shown in the drawing; they should be arranged at an angle of 30° to 45° from the vertical (Fig. 1). Tie a washer or small weight to one end of each long string; thread the other ends through the straws and tie them to the ends of the piece of wood.
2. Use the short piece of string to tie the middle of the wood to a suspension point so that the wood can pivot easily.

So what happened?

By pulling the strings alternately the card is made to climb upwards.

What next?

1. Investigate what happens if the strings are held slightly apart from each other while at the same time pulling alternately.
2. What will happen if the strings are brought together while being pulled alternately?
3. At what angle should the straws be fixed to achieve the best effect?
4. Design a climbing animal figure.

Defying gravity

An alternative demonstration of the Bernoulli effect

You will need....

- ✓ two straws
- ✓ two pieces of card (e.g. 5 × 5 and 10 × 10 cm)
- ✓ a pin (or piece of wire)
- ✓ some glue
- ✓ a punch or cork borer

Background:

According to Bernoulli's Principle an increase in the velocity of a fluid is accompanied by a decrease in its pressure and/or a change in its gravitational potential energy. ($\Delta p \propto \Delta v^2$)

Follow these steps:

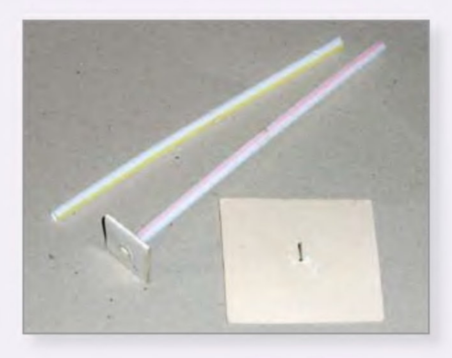
1. Punch a hole in the small card so that a straw can be fitted and glued in place.
2. Insert the pin through the centre of the larger card and glue it in place.
3. Place the card on top of the ordinary straw, with the pin facing downwards. Blow into the straw.
4. Place the card on top of the straw with the flange, with the pin facing downwards. Blow into the straw.

So what happened?

The card is easily dislodged from the ordinary straw but if it is similarly placed on the straw with the flange it cannot be blown off. In fact it will stay even when the assembly is inverted as long as there is a sufficient current of air. As the air enters the small gap between the card and the flange its velocity increases and its pressure decreases.

What next?

1. How small can the flange be and still hold the card in place?
2. Can the card be made to rotate?
3. Does the diameter of the straw make a difference?



Forces

Forces in Action

Gravitational forces pull the centre of gravity to its lowest possible point

You will need....

- ✓ Two dowels (approximately one metre long)
- ✓ two funnels
- ✓ Adhesive tape
- ✓ Blocks or books as supports

Background:

The force of gravity attracts objects towards the earth. When a body is released from rest and is free to move under the force of gravity it moves to a position in which its centre of gravity is lowest.

The double-cone roller appears to roll uphill; however its centre of gravity drops in the process.

The origin of this demonstration is unclear but it featured in a book published in 1694 where it is attributed to 'J.P.'

Follow these steps:

1. Use the books and the two dowels to make a sloped track.
2. Join the two funnels together with tape to form a double-cone roller.
3. Adjust the dowels so that the top of the track is wider than the bottom.
4. Put the joined funnels at the bottom end of the track and observe.

So what happened?

The funnels roll up the track apparently against gravity. As they roll towards the wider end of the track their centre of gravity drops.

What next?

1. Find the position of the centre of gravity of other objects e.g. wine glass, double-decker (toy) bus.



Paper helicopters

Modelling flight

You will need....

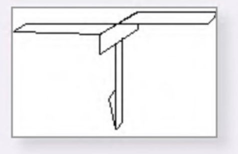
- ✓ paper (5 × 15 cm)
- ✓ paperclips
- ✓ scissors

Background

Students observe helicopter motion and investigate the factors that affect it.

Follow these steps:

1. On a piece of paper make a drawing like the one shown. (Alternatively, make a photocopy of this template.)
2. Cut along the three solid lines.
3. Fold flap A forward and flap B to the back.
4. Fold flaps C and D both forward along the dotted lines.
5. Fold along the dotted line E upward to give a weight at the bottom and to retain C and D in place.
6. Place paperclip on the flap E.

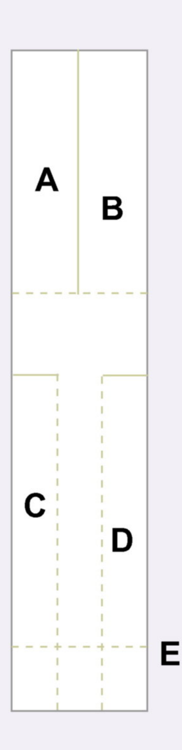


So what happened?

The paper spins as it falls. The spinning slows the fall.

What next?

1. Investigate how the weight affects the time for the helicopter to drop from a fixed height.
2. Explore the effectiveness of other designs and other sizes.
3. Observe the direction of spin and investigate the effect of folding the blades differently.
4. Explore instances of this effect in nature, e.g. seed dispersal.



Forces

How Archimedes won at 'Tug of War'

Demonstrating how pulleys work

You will need....

- ✓ 2 pieces of broom handles (or bars from retort stands)
- ✓ 1 rope
- ✓ 3 students

Background:

This demonstration is based on a crude version of Archimedes's compound pulley - a forerunner of 'the block and tackle' which is used for lifting heavy loads.

Follow these steps:

1. Take three students, two against one.
2. Ask who would win a 'Tug of War' contest
3. Arrange the rope as shown.
4. Two students try to hold the handles steady and the third student pulls the rope.

So what happened?

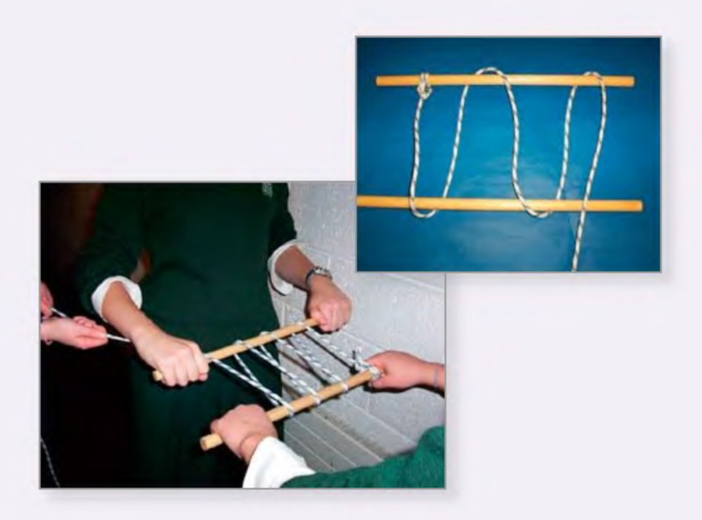
The third student has no problem pulling the rope and bringing the handles together.

The pulley exchanges a small movement with large effort for large movement with less effort involved.

What next?

1. Discuss the principle of machines leading to an understanding of efficiency as:

$$\frac{\text{mechanical advantage}}{\text{velocity ratio.}}$$



An air-powered straw rocket

Demonstrating Newton's Third Law

You will need....

- ✓ a 500 ml flexible plastic bottle
- ✓ a light plastic tube
- ✓ a drinking straw that can fit loosely over the plastic tube
- ✓ a small punch or auger
- ✓ a glue gun

Background:

Compressed air can be used to propel a straw rocket.

Follow these steps:

1. Bore a hole in the cap of the bottle just large enough to hold the plastic tube.
2. Insert the tube in the hole and attach it with hot glue.
3. Seal the straw at one end using a little hot glue or adhesive putty.
4. Place the straw on the plastic tube as shown in the picture.
5. Squeeze the bottle sharply.

So what happened?

When the bottle is squeezed sharply the straw rocket takes off.

What next?

1. Fins of adhesive tape can be fitted to the straw.
2. Investigate the relationship between the range and the mass of the 'rocket' – which can be weighted with adhesive putty.





Forces

Spinning Xs and Os

A puzzling demonstration

You will need....

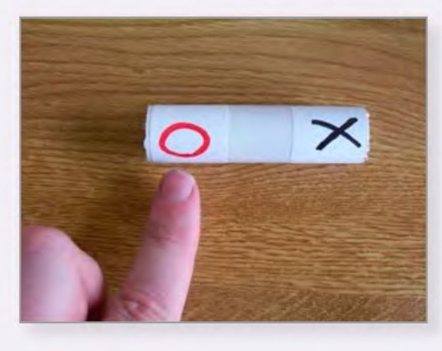
- ✓ A piece of plastic pipe
- ✓ Coloured pens
- ✓ Sticky labels
- ✓ A flat surface

Background:

Human vision cannot detect images that are moving very fast.

Follow these steps:

1. Cut the plastic pipe so that its length is at least three times its diameter
2. Stick labels on each end.
3. Mark a red **O** on one end and a black X on the other.
4. Position the pipe on a flat surface with plenty of space.
5. Place your finger on one end and press down as you pull this end towards you. This causes the pipe to spin and rotate. Observe what happens



So what happened?

The pipe rotates around a vertical axis through its centre. It also spins around a horizontal axis through its centre, corresponding with the long axis of the pipe.

If you pressed the X then as it moves the 'X' is spinning (around the horizontal axis) towards you while it is rotating (around the vertical axis) away form you. These two motions cancel one another to some extent and the 'X' can be seen.

Meanwhile the corresponding motions for the 'O' are in the same direction and it is moving so fast that it cannot be seen.

It is interesting to note that the shape of the mark appears distorted so the X changes to a Y. Also if the length is approximately three times the diameter three images are seen.

What next?

1. Try different markings and colours on the pipe.
2. View the motion in different types of light, fluorescent which has a frequency and sunlight which is not stroboscopic.
3. Use a camcorder to record the motion and playback in slow motion.
4. Try different lengths of pipe.

Resonance – with apples

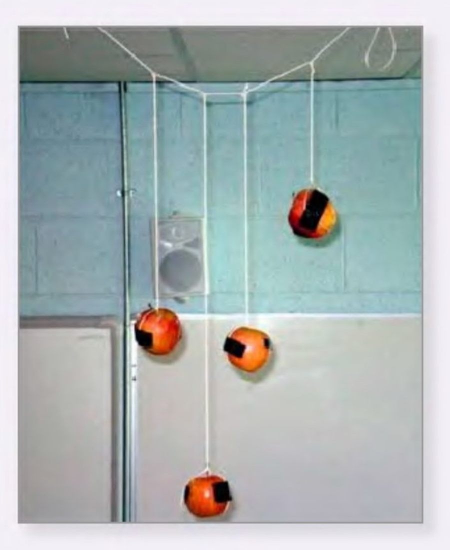
A fruity Barton's pendulum

You will need....

✓ apples
✓ a length of string (ca. 2 m)

Background:

Barton's pendulum is used to demonstrate resonance; apples can be used as the masses to introduce a discussion of Newton and his role in developing our understanding of gravity.



Follow these steps:

1. Tie the apples to lengths of cord, but have two lengths the same, and tie all of these to a second, suspended cord as shown.
2. Set one of equal-length apples in motion, and get the students to predict what will happen next.

So what happened?

Only the apple which was hanging from the same length of cord moved noticeably.

What next?

1. The weight of the apple is roughly one newton, and this can be used to tell the story of Newton and the apple which (as the story goes) fell on his head, and caused him to question why apples fall down in the first place.

Forces

The amazing swinging coat hanger and coin

Balance and centripetal force

You will need....

- ✓ a wire coat hanger
- ✓ a suitable large coin; €2 works well
- ✓ a file
- ✓ a little time and patience

Background:

This is a fun way to demonstrate circular motion using every day items.

The same forces are experienced by a sock in washing machine causing it to stick to the side of the rotating drum.



Follow these steps:

1. Keeping the hanger flat on a surface, carefully pull it out so that it forms a square.
2. File the end of the hook flat and bend it so that it points towards the opposite corner of the square.
3. Place the coin on the hook.
4. With one finger at the top carefully start to swing the hanger.

So what happened?

Amazingly, the centripetal force keeps the coin in place while the hanger swings.

What next?

1. With practise it is possible to add more than one coin and to stop the swinging hanger with the coin in place.
2. Investigate other instances of centripetal force e.g. swinging a bucket of water.

The Apple, the Hammer and Sir Isaac Newton

A stunning example of Newton's laws of motion



You will need....

- ✓ an apple
- ✓ a hammer
- ✓ a knitting needle/skewer

Background

A small force cannot accelerate a large mass at a high rate.

Follow these steps:

1. Put the knitting needle through the apple until the point is protruding about 5 cm.
2. Hold the knitting needle tightly in a horizontal position. Tap the flat end with the hammer and observe what happens to the apple.
3. Hold the knitting needle in a vertical position. Tap the flat end with the hammer and again observe what happens to the apple.



So what happened?

In both cases the needle moves through the apple because the apple has inertia.

What next?

1. How critical is the diameter of the knitting needle?
2. Compare the frictional force and the weight of the apple. Is there a critical weight for the apple?

Forces

The Leaning Tower of Jenga Blocks

A study of balance and centre of gravity that has mathematical applications

You will need....

- ✓ Stack of uniform blocks
- ✓ A steady hand
- ✓ Time and patience

Background:

Simple wooden blocks can be stacked so as to seem to defy gravity.

Follow these steps:

1. Stack the blocks on top of each other to make the tower.
2. Adjust the top block so that it overhangs the tower as much as possible without falling (almost half).
3. Move the top two blocks together so they overhang the third block (almost a quarter).
4. Move the top three blocks together so they overhang the fourth block (almost one sixth).
5. Continue down the stack.

So what happened?

With just four blocks the top block can extend completely beyond the base of the stack.

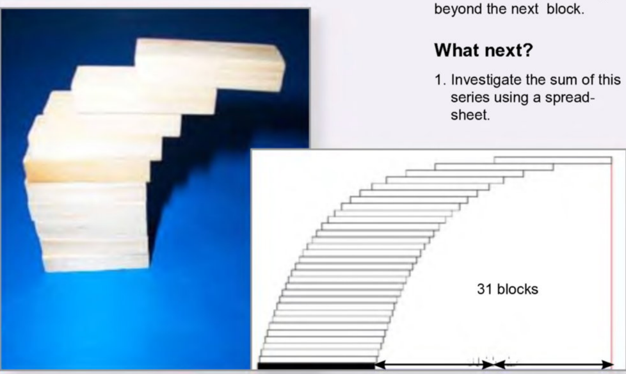
With 31 blocks the top block can extend more than two block lengths beyond the base (the table edge).

Number	Cumulative Extension
1	0.50
2	0.75
3	0.91
4	1.04
5	1.14
6	1.22
7	1.29
8	1.35
9	1.41
10	1.46
11	1.50
...	...
30	1.99
31	2.01
etc.	

In general the n^{th} block, counting from the top, can be moved $1/(2n)$ of its length beyond the next block.

What next?

1. Investigate the sum of this series using a spread-sheet.



The mighty pantograph

Drawing with levers

You will need....

- ✓ lengths of wood (or spars of other rigid material)
- ✓ pointer and a felt-tip pen
- ✓ some nuts and bolts
- ✓ panel pin or a nail
- ✓ drawing board

Background:

A pantograph is an instrument that can be used to draw magnified or reduced images. Its structure is based on interlinking levers.

Follow these steps:

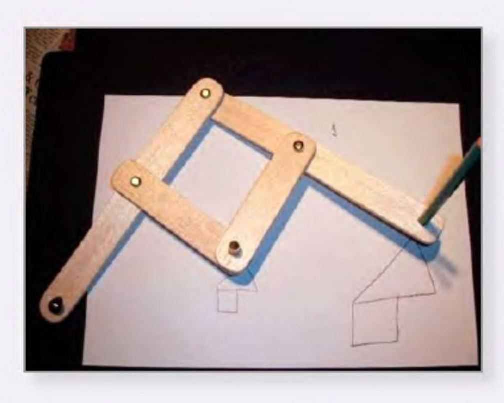
1. Cut two pieces of wood of equal length and drill three holes in each…one hole at each end and one in the middle. Cut two more pieces of half the length of the long pieces. Drill two holes in each, one at each end.
2. Join the pieces as in the picture.
3. Attach the pantograph to the drawing board using a panel pin. The pen goes on the other side and the pointer in the middle.
4. Move the pointer round the picture.

So what happened?

The sets of levers move in tandem to reproduce the copy. Four levers are linked via a flexible joint (nuts and bolts) and allow the pointer and pen to move around the drawing surface.

What next?

1. Investigate the use of the 'pantograph' shape in electrical transport.
2. Investigate how to stretch, squash or even title the drawings…perhaps having more holes to vary the arm lengths?



Forces

The power of the wind

A functioning wind-powered electric current generator

You will need....

- ✓ a 9 V Lego motor and matching cable
- ✓ LED
- ✓ some Lego spars etc.
- ✓ an aluminium can
- ✓ a ruler, marker and scissors
- ✓ a glue gun

Background:

The Lego motor can convert rotational energy into electrical energy and vice versa; it can act as an electric current generator.



Follow these steps:

1. Cut the top off the can. Measure the circumference of the can and mark out the edges of the blades.
2. Cut the blades (three sides only) using the scissors and bend the blades at an angle.
3. Glue an axle fitting to the base of the can and attach it to the motor.
4. Construct a support. Connect the motor and the LED.

So what happened?

When wind blows the blades of the motor turn and generates electricity.

What next?

1. Experiment with different blade designs.
2. Calculate the efficiency assuming that the total energy (E) of the air moving through the blades in a given time (T) is:

$$E = \tfrac{1}{2} mv^2$$

where m is the mass of air moving through the blades and v is its velocity.

$$E = \tfrac{1}{2} (\rho.\mathbf{V})(v^2)$$

where $\mathbf{V}$ is the volume of air and ρ is its density.

$$E = \tfrac{1}{2} (\rho.2\pi\ r\ v)(v^2)$$

$$E = \rho\ \pi\ r\ v^3$$

Hence the available wind energy is proportional to its wind velocity cubed. If the wind speed doubles then the available energy is eight times greater.

A brick seismograph

A demonstration model of a seismograph

You will need:

✓ 2 bricks (or heavy timber)
✓ Pencil
✓ Ring stand
✓ Adhesive tape
✓ Paper

Background:

Earthquakes are measured (detected and recorded) by an instrument called a seismograph.

Follow these steps:

1. Tie the pencil between the two bricks. Leave the point of the pencil emerging.
2. Suspend the bricks and pencil from the ring stand; the stand may need to be secured to the table with a G-clamp.
3. Tape some paper to the table and adjust the pencil so that it touches it.
4. Give the table a sharp push to one side and observe.

So what happened?

The pencil makes a mark on the paper. The brick held it still while the table and ring stand moved.

When an earthquake occurs, the seismograph chart moves with the rest of the earth. But the marking pen is attached to a freely hanging weight. When subjected to a shock the pen and chart do not move together and their relative motion produces a trace on the chart.





What next?

1. Discuss causes and consequences of earthquakes.
2. Explore the use of electromagnetic vibration detectors.

Heat

Go for burn

Conversion of energy using a home-made vegetable candle

You will need....

- ✓ tea light
- ✓ vegetable oil
- ✓ test tube, water and thermometer.
- ✓ Evaporating dish to catch any spilt oil.

Background:

Burning foods to show the energy conversion is very common. However only a few foods like crisps burn well. The vegetable oil candle provides a simple alternative and also gives great flexibility. The wax need not go to waste; a match stick can act as a new wick.

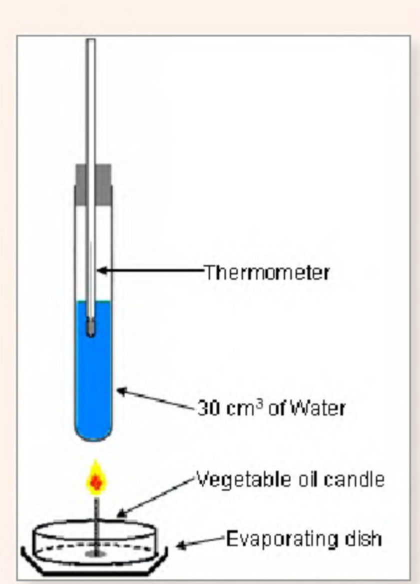
Follow these steps:

1. Melt and discard the wax from a tea light, leaving the wick intact.
2. Add a little vegetable oil.
3. Light the candle and record the temperature every 10 seconds.
4. Keep the candle in an evaporating dish.

Safety

! Hot oil can cause severe burns.

! For students' safety peanuts should not be used.



So what happened?

The vegetable oil burns like any other fuel converting the chemical energy to heat and light energy.

What next?

1. By changing the type of oil a simple study can be made of the oil's energy content by volume.
2. Carry out the experiment with the burning candle on top of a mass balance so you can view the change in mass and temperature at the same time.
3. You can make a candle from a satsuma orange using a little vegetable oil and the orange 'core' as a wick.

Latent Heat

Cooling by evaporation

You will need....

- ✓ 3 thermometers
- ✓ 3 pieces of cotton wool
- ✓ 3 rubber bands
- ✓ Ethanol
- ✓ Water (at room temperature)

Background:

Energy is needed to vaporise a liquid. If heat is not added then the phase change results in a drop in temperature.

This effect is used in meteorology.



Follow these steps:

1. Place a piece of cotton wool around the bottom of each thermometer securing it with a rubber band.
2. Stand up the first thermometer with dry cotton wool.
3. Soak the second thermometer in the container of water and stand beside the first.
4. Soak the third thermometer in the container of ethanol and stand beside the second.
5. Observe the temperature reading of each thermometer for about 10 minutes.

So what happened?

As molecules evaporate from the two wet bulbs, energy (heat) is removed from them. Since ethanol evaporates faster than water, the thermometer with ethanol on it gets cooler than the other two.

What next?

1. Demonstrate the rapid evaporation of an alcohol by putting a drop onto the back of a student's hand and letting them experience the cooling effect.
2. Explain how "sweating" can cause a cooling effect.

Heat

Obedient Paper

Convection currents and energy transfer

You will need....

- ✓ Paper
  (4 × 8 cm is suitable)
- ✓ Pencil with sharp point

Background:

Pretend to your students that by the power of telekinesis you can command the piece of paper to spin.

Ask them to explain what is really happening.

Follow these steps:

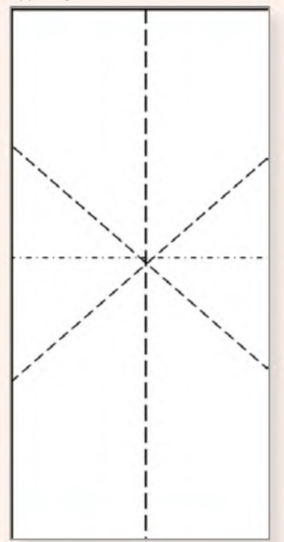
1. Take a piece of paper and fold as shown.
2. Place it on the tip of the pencil.
3. After a moment the paper will start to spin.
4. Using two hands can increase the effect.

So what happened?

The heat from your hand causes the air to heat up. A convection current is formed that causes the paper to spin.

What next?

1. This introduction to convection currents can lead to other methods of heat transfer and conservation of energy.
2. Try using a piece of paper cut in the shape of a propeller or other shapes.





Smoker in a bottle

Convection in liquids

You will need:

- ✓ 2 plastic drinks bottles
- ✓ hot and cold water
- ✓ bowl
- ✓ a piece of card (4 × 4 cm)

Background:

Warm water is less dense than cold water and tends to rise above the colder water.

The motion is reminiscent of deep-sea 'smokers'.

Follow these steps:

1. Fill one bottle with cold water and one with hot water (70° C is suitable). Add some food colouring to the hot water.
2. Place the piece of card on top of the bottle of cold water and hold it firmly in position.
3. Carefully turn the bottle of cold water upside down and put it on top of the other bottle.
4. Making sure the bottles are lined up, take out the piece of card and observe.

So what happened?

The hot water rises into the upper bottle and cold water sinks into the lower bottle.

This kind of heat transfer is called convection; it occurs in liquids and gases that are not at a uniform temperature.

What next?

1. Discuss other ways in which heat can be transferred e.g. in solids or in a vacuum.

Safety:

! Always take care with hot water.



Heat

Light mill

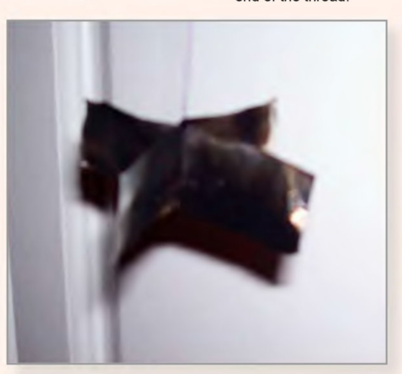
Home-made Crooke's radiometer

You will need....

- ✓ Aluminium foil
- ✓ Glue
- ✓ Fine thread
- ✓ Jar
- ✓ Candle
- ✓ Knife
- ✓ Card (10 × 10 cm)

Background:

A light mill or radiometer turns when placed in the light.



Follow these steps:

1. Cut out two pieces of aluminium foil 4 × 8 cm in size. Cut a 2 cm slit in the middle of the pieces and slot them together to form the blades of the radiometer.
2. Blacken one side of each vane using a lighted candle; holding a knife blade behind the foil may help. No two black surfaces should face one another.
3. Glue a very fine thread to the centre so that the vanes can turn horizontally.
4. Cut a slit in the centre of the card and insert the free end of the thread.
5. Suspend the vane in a tall jar and adjust the height so that the vanes are free to rotate.
6. Place the jar in the sunshine.

So what happened?

The vanes turn slowly . (They will not continue turning because the thread will twist and eventually produce an opposing torque.)

The dark sides become warmer than the shiny sides. Air molecules rebounding from these hotter sides cause a reaction which drives the vanes in the opposite direction.

In a commercial radiometer the vanes are on a pivot and so there is no opposing torque. The container is also partially evacuated and there is less air resistance. If it were completely evacuated the vanes would not rotate.

What next?

1. Investigate other designs for the radiometer (e.g. alternative suspension for the vanes).

See the IR light

Use a TV remote control and a digital camera to observe IR

You will need....

- ✓ A digital camera or camcorder
- ✓ A TV remote

Background:

Using simple everyday items infra-red radiation (IR) can be detected and observed.

Follow these steps:

1. View the transmission LED of a TV remote with a digital camera or even take a photograph as shown below.

So what happened?

The human eye cannot detect infra-red radiation. The charge-coupled device (CCD) in digital cameras and in camcorders can detect and display it.

What next?

1. Point the TV remote at a mirror, detect the reflected beam, what can you say about angle of incidence and angle of reflection?
2. Try the experiment with different devises such as camera-phone.
3. Try the experiment with other IR sources such as car remote keys, the IR on a phone.
4. Why do you think the beam flickers?
5. What other forms of the Electromagnetic Spectrum can we not see?



Light

Camera Obscura

Make a simple instrument that demonstrates optics

You will need....

- ✓ Convex lens (10 cm)
- ✓ Tubing
- ✓ Box
- ✓ Grease proof paper

Background:

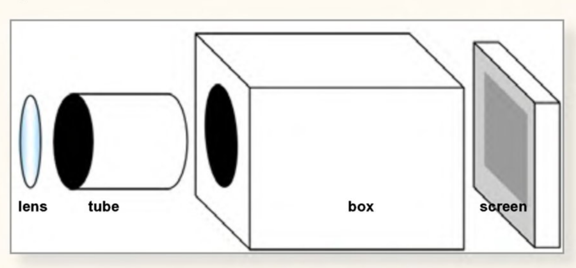
The term “camera obscura”-meaning dark room-was first used by the German astronomer Johannes Kepler in the early 17th century.

Follow these steps:

1. Construct the camera obscura by assembling the parts as shown.
2. The box has a hole cut into one end to fit the focussing tube; the other end of the box is open and the screen is inserted.
3. The inverted real image can be viewed on the screen.

What next?

1. Many people have speculated that Dutch artist Johannes Vermeer (1632-75) used a camera obscura to help him create his paintings e.g. The Music Lesson’. If so, he had to paint the pictures upside down.







A Pringles® Camera

Light travels in straight lines

You will need....

- ✓ A Pringles® empty carton (large size, 200 g)
- ✓ Craft/cutting knife
- ✓ A thumb tack
- ✓ Duct tape (or other opaque adhesive tape)
- ✓ Greaseproof paper/tracing paper
- ✓ Aluminium foil - optional
- ✓ Ruler and pencil

Background:

Light travels in straight lines.

Follow these steps:

1. Remove all dust from the Pringles® container.
2. Using the thumb tack make a hole in the centre of the metal base.
3. From the metal base measure up a third of the length of the container and cut this third off.
4. Fit a circle of greaseproof paper inside the lid of the container. Put the lid on the smaller cut off container.
5. Tape the two portions of the tube together.
6. Finally, to ensure that the 'camera' is light-tight, wrap a layer of aluminium foil around the tube.
7. The camera is now ready.



So what happened?

Light travelling in straight lines passes through the pinhole and a real inverted image is formed on the grease-proof paper.

What next?

1. Investigate whether the clarity of the image is related to the distance between the pinhole and the 'screen'.
2. Does the size of the 'pin-hole' make a difference?

Light

One spoon or two?

Deflection of laser beam by varying refractive indices

You will need....

- ✓ wedge shaped cell (transparent plastic or glass)
- ✓ laser source
- ✓ sugar solutions of known and unknown concentrations

Background:

The deflection of a beam of light by a prism depends on the angle of the prism and its refractive index, the wavelength of the light and the angle of incidence.

Using a hollow prism filled with liquid and a monochromatic light source, such as a laser, the deflection depends on the refractive index of the liquid and the angle of incidence.

Follow these steps:

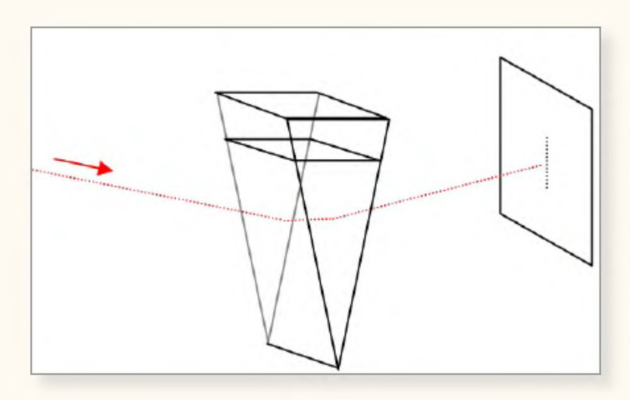
1. Set up a laser source, a screen and a wedge-shaped cell as shown in the diagram. With water in the cell, mark the position of the light on the screen.
2. Using a number of sugar solutions of known concentration mark the deflection of the light on the screen. In this way a scale can be produced.
3. If a solution of unknown concentration is used then the deflection of the light can be used to estimate the concentration.

So what happened?

The deflection of the laser beam varies with the concentration of the sugar solutions.

What next?

1. There are several more accurate ways of measuring the concentration of solutions (titration, density, colour etc.). However this method could be adapted for continuous monitoring of the concentration of a flowing solution.



Classroom optics

Measure the refractive index using an OHP

You will need....

- ✓ Overhead projector (OHP)
- ✓ Glass block
- ✓ Pin, cork
- ✓ stand,
- ✓ transparency, pen, ruler

Background:

Many school textbooks over complicate this experiment by including the use of a plane mirror. This introduces a second image and an indirect method of measuring the apparent depth – which often confuses students.

At POS3 the Czech team demonstrated an alternative method (see http://www.scienceonstage.ie/books/POS3_booklet_Ireland.pdf) This method can be demonstrated to a whole class.





Follow these steps:

1. Write the word "Physics" on the transparency with a fine pen. Then place a block of glass on top of it.
2. Focus the OHP so that the image on the screen is sharp.
3. Move the pin up the block until its image is also sharp on the screen.
4. Measure the height of the block (*Real Depth*) and the distance from the top of the block to the pin (*Apparent Depth*).
5. Use *Real Depth / Apparent Depth* to calculate the refractive index of the medium.

So what happened?

The position at which the image of the pin is in focus marks the apparent depth.

What next?

1. The same method can be used to measure the refractive index of a liquid by placing a pin in the bottom of the container filled with the liquid.

Light

The silver egg

A fun way to demonstrate total internal reflection

You will need....

- ✓ A hard-boiled egg or golf ball
- ✓ A glass of water
- ✓ A candle

Background:

Air trapped beneath water provides a different refractive index, which can result in total internal reflection.

Follow these steps:

1. Place the egg in the flame of the candle and cover it with soot.
2. Place the egg in the glass of water.
3. View the egg through the water.

So what happened?

The egg appears silvery because of the thin film of air clinging to the soot.

What next?

1. A similar demonstration “How to make a wooden mirror” can be found in the Irish POS3 booklet page 34 downloadable from http://www.scienceon-stage.ie/books/POS3_booklet_Ireland.pdf



Underwater Candle

Optical illusions using refraction and reflection

You will need....

- ✓ Cardboard box
- ✓ Piece of cardboard
- ✓ Black matt spray paint
- ✓ Sheet of glass (20 x 25 cm)
- ✓ Candle
- ✓ Glass
- ✓ Water
- ✓ Utility knife
- ✓ Matches/lighter

Background

Images can be formed by a combination of optical phenomena.

Follow these steps:

1. Use the knife to cut and fit the piece of cardboard snugly diagonally inside the box.
2. Measure and cut out a small viewing window (15 cm square) in the front left hand of the box.
3. Remove the divider from the box and cut a window about 15 x 20 cm that will line up with the viewing window, allowing you to look straight through the left rear side of the box.
4. Spray the divider and the inside of the box with the black paint.
5. Use tape or glue to secure the glass over the opening in the divider.
6. Mount the candle in the centre of the first compartment and light the candle.
7. Place the glass in the centre of the rear compartment.
8. Look through the viewing window and through the glass window and align the candle and glass until the candle appears in the centre of the glass.
9. Watch though the window while filling the glass with water.



So what happened?

It appears as though the candle is burning in a glass of water. This happens because the light from the front of the glass window reflects the image of the candle, while we can still look through the window to see the glass of water behind.

What next?

1. This optical illusion is used in circus sideshows to create the illusion of a human turning into a skeleton or a monster and is referred to a Pepper's Ghost.

Light

Light Reflectors

Comparison of black and white surfaces

You will need....

- ✓ One sheet of black paper
- ✓ One sheet of white paper
- ✓ Two acetate sheets
- ✓ 2 similar torches

Background:

Dark dull surfaces are poor reflectors while bright shining surfaces are good reflectors.

Follow these steps:

1. Fix the black paper to one of the acetate sheets and fix the white paper to the other. You now have sheets with a shiny surface and a matt surface.
2. Stand the two matt surfaces side by side. Place the two torches equidistance from the papers so that one will shine on the white and the other on the black.
3. Ask the students to predict which surface will be the better reflector.
4. Switch both torches on and compare the effects on the surfaces.
5. Repeat the test using the shiny surfaces.

So what happened?

The patterns observed on the white surfaces are very obvious while those on the dark surfaces are not.

What next?

1. If a digital lux meter is available the reflectivity of the surfaces can be compared.
2. Explore the reflective properties of different types of surfaces and different colours.
3. Explore the role of colour and texture in photography.



LED colour mixing

Use bright LEDs to show colour mixing

You will need....

- ✓ 3 bright LEDs (clear white) as found in some key-ring lights
- ✓ 3 V battery
- ✓ red, green and blue filters (theatre quality)
- ✓ ribbon cable (30 cm)
- ✓ some Lego parts
- ✓ glue gun
- ✓ soldering facility

Background:

Very bright white light LEDs are becoming more available and although their spectrum is not uniformly bright at all visible wavelengths they emit strongly in red, green and blue. In fact the blue is often too strong.

Follow these steps:

1. Solder wire connections to the three LEDs; these can be linked in parallel at either end (the battery end or the LED end). If a 3 V source is used then no resistor is necessary.
2. Attach the LEDs to small Lego bricks using hot glue.
3. Cut small pieces of the filters and glue them in front of the LEDs; two layers of blue filter may be necessary.
4. The advantage of this assembly is that the direction of the beams can be easily changed.

So what happened?

Direct the three beams onto one spot on a screen of white paper or card.

White light is seen on the screen.

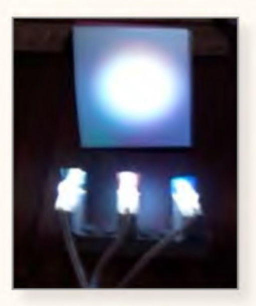
Block the beams one by one and note the colour on the screen.

Move the lights closer to the screen and the individual colours can be seen.

What next?

1. Investigate the effectiveness of single-colour LEDs for colour mixing experiments.





Materials

Baby nappy secret

Non-toxic polymer absorbs moisture

You will need....

- ✓ a disposable nappy (diaper)
- ✓ zip-lock bag
- ✓ scissors
- ✓ water
- ✓ dropper

Background:

Disposable nappies contain tiny crystals of a non-toxic polymer that absorbs water and draws it away from the baby's skin.

Follow these steps:

1. Take a new unused nappy and carefully cut the inside lining and remove all the cotton like material. Put all the stuffing material into a clean, zip-lock bag.
2. Blow a little air into the bag to make it puff up like a pillow, seal the bag.
3. Shake the bag for a few minutes to remove the powdery polymer from the stuffing.
4. Carefully remove the stuffing from the bag. The dry polymer is collected in the bag.
5. To see how much water it can hold add water using the dropper drop by drop.

So what happened?

The fine powder found in nappies is sodium polyacrylate; it absorbs between 800 and 1000 times its own weight of water. The cotton-like fibres help to spread out both the polymer and the water. It can be seen that a little bit of powder can hold a large amount of water but it has its limits.



What next?

1. Add salt to the gel and see what happens.

Cement-mixing in the classroom

Making and testing cement as an introduction to mixtures and forces

You will need....

- ✓ Small quantities of each of the following: cement, sand, water.
- ✓ Additives: gravel, sugar, salt, talcum powder, plaster...
- ✓ Ice cube trays, newspaper, used plastic containers.

Background:

This activity deals with mixtures and the purpose of additives to a mix of cement and sand. Students also measure volumes in terms of ratios.

The strength of the 'bricks' is tested.

Follow these steps:

1. Measure out the cement, sand, water and one of the additives in the ratio of 2: 2: 2: 1 respectively.
2. Prepare two mixtures – one of cement, sand and water and the other one of cement, sand, water and an additive.
3. Add the water, small quantity at a time while mixing.
4. Make the 'blocks' by pouring the cement into the ice cube tray and leave it aside to set for a day or two.
5. When the blocks have set remove them from the plastic tray.
6. Using a G-clamp count how many turns are required to crack the blocks.
7. Repeat using different additives.

So what happened?

The additive affects the strength of the block.

What next?

1. How is the setting time affected by the temperature of the water that is added?
2. How is the strength of the blocks affected by lowering the setting temperature e.g. by leaving the block to set in a refrigerator?
3. Since the blocks are wedge-shaped they might be used to construct an arch bridge.

Materials

Gas Model

A physical model of molecular energy

You will need....

- ✓ 12 or more table tennis balls of different colours (or polystyrene balls approximately 3 cm in diameter)
- ✓ A small cage with wire mesh on all sides. (A small rodent trap could be used.)
- ✓ Short pieces of wire or twist ties
- ✓ A hair dryer, fan, or other air blower

Background:

According to the atomic theory of matter a gas is made up of tiny particles (atoms or molecules) which are constantly in motion, colliding with one another and with the walls of their container, if there is one. Here is a highly visual model of this theory.

Follow these steps:

1. Place the balls in the cage and secure the door.
2. Hold the blower under the cage and blow air up through it. The moving air will agitate the balls, simulating the kinetic behaviour of a gas.
3. Watching the coloured ball will allow you to follow the motion of a single "molecule".
4. By adjusting the speed of the blower from the cage, you can simulate heating and cooling a gas. The faster the balls are moving, the hotter the gas.
5. Listen for the clicking of the balls against the walls of the cage. At lower "temperatures," the clicking is quieter and occurs at a slower rate.



So what happened?

Adding heat (simulated by the blower) to a gas increases its internal energy. The molecules of the gas move faster and strike the walls of their container more often, yielding an increase in pressure (force per area). This increased pressure is simulated by the faster motion of the balls, which strike the sides of the cage more often. Cooling the gas (moving the blower farther from the cage) lowers the internal energy, slowing the motion of the molecules, and thus lowering the pressure

What next?

1. Try using cages of different volumes. In this way, you can model the ideal gas law by changing temperature, pressure, and volume.
2. If you blow air on one side of the bottom of the cage and not the other, the balls will eventually "condense out." That is, they will form a pile on the side away from the blower, where it is "cooler."

Cool science

Simulation of glacier motion

You will need:

- ✓ 2 small sheet of glass
- ✓ Sand
- ✓ Ice cubes
- ✓ Table top

Background:

Glaciers are large masses of moving ice and snow. Glaciers move because the pressure of overlying layers of snow upon the bottom layers causes the snow at the bottom to melt and to move. How fast a glacier moves depends on the steepness of the slope of the terrain over which it travels, temperature changes and the nature of the underlying rock surfaces.

Follow these steps:

1. Arrange the materials glass, sand and ice as shown below.
2. Press down lightly on the ice cubes with your hand and push them over the sand. Continue the movement over the second sheet of glass.
3. Examine the surface of the second sheet of glass.

So what happened?

The glass has scratches on its surface. This is like the action of a real glacier because the ice cube picked up sand grains and used them as cutting tools.

Safety:

! Beware of jagged or sharp glass edges.

What next?

1. Investigate the effect of using different materials.



Materials

Iso and Thixo

Non-Newtonian fluids

You will need....

✓ custard or cornflour
✓ water
✓ mixing bowl / used yoghurt containers
✓ spoon/stirrer

Background:

Non-Newtonian fluids do exhibit variable viscosity depending on the applied external shear force.

Isotropy is a property whereby a mixture when agitated exhibits solid properties and exhibits liquid properties when left standing.

Thixotropy is a property whereby a mixture behaves more like a liquid on being agitated and more like a solid when left standing.

Follow these steps:

1. Spoon a small quantity of custard into the container.
2. Add a lesser quantity of water while stirring until the mixture is fluid.
3. Scoop some of the mixture onto your hand and squeeze it. Observe what happens to the mixture.
4. Open your hand and observe what now happens.
5. Use your hand or fist to 'stab' the mixture.
6. Now let your hand just rest on the surface.
7. Quickly pull your hand from the surface.

So what happened?

Applying a rapid external stress causes the mixture to exhibit solid properties. When a more gentle stress is applied to the surface the mixture becomes more fluid.

What next?

1. Investigate the role played by these non-Newtonian fluids in geology, paints and gels.



Tearing Tissues

Forces and compaction

You will need....

- ✓ two facial tissues
- ✓ one rubber band
- ✓ one container of salt
- ✓ an empty paper towel /toilet roll tube
- ✓ one wooden dowel (or broom handle)

Background:

The effect of a force depends on the nature of the material to which it is applied. When compacted powders may behave as solids.

Follow these steps:

1. Unfold one facial tissue and try tearing it apart. Why was it so easy to tear? In a moment you are going to try to tear the second piece of facial tissue, but first you will need to prepare it.
2. Unfold the second tissue and drape it over one end of your cardboard tube. Holding it firmly, attach it to that end of the tube with a rubber band.
3. Place the tube vertically on a flat surface with the tissue at the bottom
4. Pour about 8 cm of salt inside the tube and tap it down gently a few times.
5. Now get someone to lift the tube and hold it vertically.
6. Push the dowel downward through the inside of the tube.

So what happened?

One might expect that the force applied through the dowel would push the salt out of the tube, tearing the tissue.

However the force compacts the salt even more. It tightens against the sides of the tube and behaves as a solid lump.

What next?

1. Explore the effect of varying the depth of the salt.
2. Explore the effect of varying the diameter of the cylinder.



Materials

Plastic Milk

Proteins in milk

You will need….

- ✓ 1 cup whole milk
- ✓ White vinegar
- ✓ Small saucepan
- ✓ Hotplate
- ✓ Teaspoon
- ✓ Wax paper
- ✓ Glass jar

Background:

The casein (protein) from milk hardens into plastic.

Follow these steps:

1. Pour the milk into the saucepan; add 2 teaspoons of vinegar and heat, stirring continuously.
2. When the milk boils, tiny lumps (curd) will form in a clear liquid (whey).
3. Spoon the curds into the glass jar.
4. Add 1 teaspoon of vinegar to the curds and let the mixture stand for one to two hours.
5. The curds will form a yellowish glob at the bottom of a clear liquid.
6. Pour out the liquid and remove and wash the yellow glob with water.
7. Knead the glob until it attains the consistency of dough.
8. Mould the dough into any shape and place it on the wax paper and dry overnight.



So what happened?

The combination of heat and acetic acid precipitates the casein from the milk.

What next?

1. You can make glue from milk by adding 1/3 cup vinegar to one cup of milk in a wide mouthed jar. When the milk separates into curds and whey, pour off the liquid and wash it away. Add one-quarter cup of water and a tablespoon of baking soda. When the bubbling stops, you've got glue.

Smelly Balloons

Permeability of rubber and diffusion of gases

You will need....

- ✓ Coloured balloons,
- ✓ Flavouring extracts (coconut, lemon, vanilla, etc.)

Background:

This activity demonstrates the permeability of the rubber balloon. Students will be able to detect the escape of the molecules through the microscopic pores of the balloons by smelling them.

Follow these steps:

1. Place a few drops (1-2) drops of extract in each balloon.
2. Rub or squeeze the balloon to distribute the extract.
3. Inflate and seal the balloons.
4. Smell the balloons and record your observations.

So what happened?

Molecules of the scents or flavours escaped through the microscopic pores of the balloons and were detected by their smell.

Air also escapes and over a few days the balloons partially deflate.

What next?

1. Investigate other examples of diffusion of gases.



Pressure

Seat of nails

Experience pressure, force and area for yourself

You will need...

✓ a board (30 × 30 × 2 cm)
✓ a pencil and ruler
✓ 250 nails (4 cm)

Background:

When the force of an object is concentrated into a small area the pressure is high and an object may sink into the surface.

If however the force is spread over a large area the pressure is low and the object will not sink.

pressure = force / area



Follow these steps:

1. Draw a line along the four sides of the board, 1 cm from the edge.
2. Place marks on the lines 2 cm apart.
3. Draw lines to join opposite points. This will form a grid.
4. Hammer a nail into the board at each grid point. This will require 225 nails.
5. Place the board on a chair or stool and invite the students sit on it.

So what happened?

When the students sit on the seat of nails their weight is spread over a large area and the pressure is low so the nails don't pierce the skin.

What next?

1. Once the students understand the inverse relationship between pressure and area they could then move on to investigate hydraulics.

Safety

! Care must be exercised in using this device. If a person's weight is spread over a small area then there is a greater danger of injury. This is particularly likely when a person is getting up from the 'seat of nails' as they may use their hands to raise themselves and inadvertently place them on the sides of the board.

Are two straws better than one?

Atmospheric pressure and suction

You will need....

✓ A glass of water
✓ Two straws

Background:

A pressure difference is required raise the level of water in a tube.

Follow these steps:

1. Put a straw in the glass of water.
2. Hold a second straw outside the glass as shown.
3. Try sucking the water up through the straw.

So what happened?

The student will find it impossible to drink if one of the straws is outside the glass.

If both straws are placed in the mouth it is difficult to maintain a sufficiently low pressure to cause the water to be sucked up because air enters through the second straw.

What next?

1. Does the diameter or length of the straws make a difference?
2. By joining straws together find out the longest straw that it is possible to drink through.



Pressure

Balloon in a Bottle

Atmospheric pressure and sleight of hand

You will need....

- ✓ A well stretched balloon
- ✓ A clear plastic bottle with stiff sides

Background:

By forcing the air out of the bottle a balloon will stay inflated. This can be used to teach aspects of air pressure and vacuums.

Follow these steps:

1. Place the balloon inside the bottle; spread its neck over the top of the bottle.
2. Place a small hole near the bottom of the bottle. Conceal this hole with your thumb for the moment.
3. Blow up the balloon, air will exit via the hole.
4. Quickly seal the hole with your thumb and the bal- loon will stay inflated.
5. At this stage you can put a pencil or even water into the balloon.
6. By slowing allowing air to enter the bottle, the bal- loon will deflate under your command.

So what happened?

There is low pressure in the bottle, lower than the air pressure in the balloon which is equal to the pressure of the atmosphere.

What next?

1. Discuss why it is not possible to blow up the balloon without the hole in the bottle.
2. Putting tape over the hole can leave the balloon inflated.
3. By sucking air out through the hole you will be able to inflate the balloon.



Bionic Plungers

Experience the force of the atmosphere

You will need...

- ✓ Two heavy rubber plungers (one of them with a small hole in it)

Background:

The atmosphere exerts a pressure on everything on Earth but why doesn't it crush us?

Follow these steps:

1. Push plungers together and pull them apart. This can be done relatively easily.
2. Now tell students that you have bionic strength and can hold the plungers together while others try to separate them.
3. Let students push plungers together and then cover the hole with your finger. Students will not be able to pull plungers apart and will be amazed at your bionic strength.

So what happened?

The plungers were easy to separate when the hole was uncovered. This allowed air to enter. Covering the hole prevented air from entering and when the students tried to pull them apart, the volume increased between the plungers, thus decreasing the pressure. The atmospheric air pressure held the two plungers together.

The size of the force depends on the pressure difference between the inside and the outside and on the area of the open end of the plunger. It is typically several hundred newtons or roughly the weight of a student.

What next?

1. Students could perform the collapsing can experiment and watch as the atmospheric pressure crushes a can.
2. They can also begin to provide explanations for everyday phenomena such as why aeroplane cabins need to be pressurised.
3. Estimate the volume change and hence the pressure change when the plungers are pulled. Measure the area and calculate the force. Verify the answer by measuring the force.
4. Learn more about Otto von Guericke's demonstration of the Magdeburg hemispheres in 1654.



Pressure

Simple hovercraft

The effect of reduced friction

You will need...

- ✓ Balloon
- ✓ CD
- ✓ Empty thread spool
- ✓ Glue

Background:

A hovercraft uses a cushion of air to reduce friction.

Follow these steps:

1. Use the glue to stick the CD to the bottom of the spool.
2. Inflate the balloon.
3. Stretch the mouth of the inflated balloon over the top of the spool.
4. Put the assembly on the table and observe.

So what happened?

Air from the balloon escapes through the hole in the centre of the CD. This provides a cushion of air under the CD and reduces friction with the surface. The 'hovercraft' can then move easily across the table.

What next?

1. What is the effect of using a bigger balloon or placing it on different surfaces?
2. Find out more about different designs and uses of hovercraft.



Balloon pressure

At constant pressure the volume of a gas increases with the temperature – Charles's Law

You will need...

- ✓ A balloon
- ✓ A felt-tip pen or board marker
- ✓ A length of string (70 cm)
- ✓ A refrigerator (or ice box)
- ✓ Sunshine (or a hair dryer)

Background:

Gas expands when heated and contracts when cooled as long as the pressure remains constant.

Follow these steps:

1. Inflate the balloon and tie the neck.
2. Tie the string around the middle of the balloon until it fits snugly.
3. Mark the position of the string with the felt-tip pen.
4. Place the balloon in a sunlit window for 30 minutes and observe.
5. Place the balloon in the freezer compartment of the refrigerator for thirty minutes and observe.

So what happened?

At the start of the investigation the balloon looked like the one in Fig. 1.

After 30 minutes in the sunlit window the balloon had expanded and the string became tighter on the balloon (Fig. 2).

After 30 minutes in the refrigerator the balloon had contracted and the string became loose (Fig 3).

What next?

1. Explore how hot air balloons work?



Fig. 1

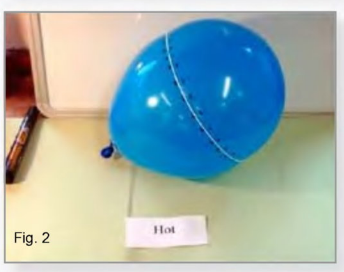


Fig. 2



Fig. 3

Waves and sound

Let's make waves

An inexpensive ripple tank

You will need:

- ✓ a speaker from an old television or stereo
- ✓ a plastic bottle with a lid
- ✓ 3 flexible straws
- ✓ an empty transparent container (e.g. Ferrero Rocher box)
- ✓ a signal generator
- ✓ a retort stand and a clamp
- ✓ glue

Background:

A ripple tank is very useful for demonstrating diffraction and interference of waves in a laboratory.

It is possible to use a speaker from an old television or stereo to make waves on water.

Follow these steps:

1. Remove the speaker from a disused radio or TV set.
2. Get a plastic bottle of the same diameter and cut out the base. Stick the speaker to it and seal the edges with adhesive tape.
3. Connect the speaker to the amplified output of a signal generator, via two leads.
4. Drill a small hole (3 or 4 mm in diameter) in the cap of the bottle, insert a straw and seal it in place with glue.
5. When the signal generator is switched on it should be possible to feel small puffs of air coming from the straw.
6. Place the container on the overhead projector and half fill it with water.
7. Arrange the apparatus so that the end of the straw is just over the water.
8. Adjust the frequency until a wave appears in the water. (typically 1 to 5 Hz).
9. Prepare a second bottle cap with two holes and two adjustable straws. This can be used to produce an interference pattern.



So what happened?

The speaker pushes the air in puffs which can be seen disturbing the water. Although the water waves are transverse the setup illustrates the propagation of waves in general, including sound waves.



What next?

1. Make plane waves by attaching a flat stick to a speaker to illustrate diffraction etc. when going through a suitable slit.
2. Remove the cap of the bottle (with the straw) and observe the effect of the puffs of air on a suspended ping pong ball. Can you show resonance by selecting a suitable frequency?
3. You could also direct the sound waves from the bottle onto a suitable surface to show reflection of sound and use a microphone to detect them. A computer running Audacity can be used to display the waveform (http://audacity.sourceforge.net/).

Stationary waves

Generate waves on a string

You will need:-

- ✓ a speaker from an old TV set
- ✓ about 3 m of hat elastic
- ✓ a signal generator.
- ✓ 2 retort stands
- ✓ 1 clamp

Background:

Standing waves can easily be demonstrated using an old speaker, a string and a signal generator.

Follow these steps:

1. Connect the speaker to the amplified output of the signal generator.
2. Tie a crocodile clip to one end of the hat elastic and attach other end to the retort stand. Leave about 10 cm of a tail on the elastic and tie this to another clamp. Insert the crocodile clip into a small cut near the edge of the paper cone.
3. Switch on the generator and adjust the frequency until a standing wave appears (about 10 to 20 Hz). The speaker vibrates but the motion creates a transverse wave on the elastic.
4. Adjust tension in elastic to get maximum amplitude on standing wave.
5. Catch the string at a node. Pull in and out and observe different harmonics appearing as you adjust the tension.
6. The distance between two nodes is half the wavelength. Record the frequency of the signal generator. Calculate the velocity of the wave using the formula: $v = f.\lambda$



So what happened?

The speaker contains a magnet and a coil which is attached to the paper cone. The AC from the signal generator causes the coil and cone to move in and out; the vibrations are transferred to the elastic producing transverse waves. At the resonant frequencies standing waves form.

What next?

1. Identify the harmonics over a range of frequencies.
2. Explore the relationship between the tension, the frequency and mass per unit length.
3. A pump from an old washing machine (permanent magnet type) can be used instead of the speaker. When driven from a signal generator the vanes can be made to oscillate.

Waves and sound

Cheap beats

Nearly equal frequencies can show interference

You will need....

✓ Two recorders – the cheaper the better!

Background:

Sound waves from sources that are nearly equal in frequency produce constructive and destructive interference. The beats can be heard as a periodic amplitude variation (tremolo) in the sound.

Follow these steps:

1. Place the two recorders in your mouth and blow them both at same time.
2. Listen carefully for the beats.

So what happened?

The cheap recorders do not produce the exact same note so interference occurs.



What next?

1. See if all the notes produce the same beat frequency.
2. Record the sounds using Audacity or observe them using an oscilloscope. If possible measure the individual frequencies and the beat frequency. The beat frequency is the difference of the individual frequencies. Audacity can be downloaded from: http://audacity.sourceforge.net/

Tuning fork beats

Nearly equal frequencies can show interference

You will need....

- ✓ Two tuning forks of the same frequency
- ✓ An elastic band

Background:

In acoustics, a beat is an interference between two sounds of slightly different frequencies, perceived as periodic variations in volume; the frequency of the beat is the difference between the two frequencies.

Follow these steps:

1. Wind the elastic band around one of the tines of one tuning fork.
2. Strike them off a surface that is not too hard (a large rubber, a wad of paper, a mouse mat etc.); this will reduce the amount of high frequency ringing.

So what happened?

The forks emit sounds of slightly different frequencies which interfere with one another and produce beats.

What next?

1. Observe musicians tuning their instruments before playing.
2. Listen to overhead aircraft whose engines are emitting sound of nearly equal frequencies.



Waves and sound

Filling a cup by ear

Standing waves in an air column

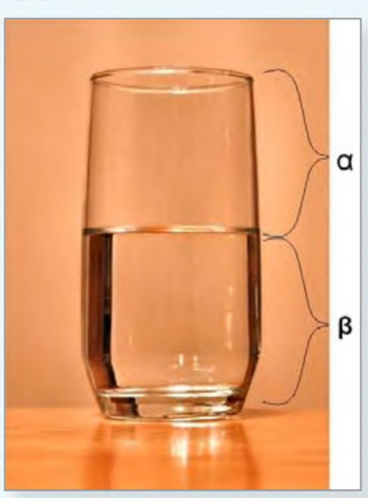
You will need....

✓ a drinking glass

✓ jug of water

Background:

The sound water makes changes as you fill a glass. Students are asked to fill a glass with water with their eyes closed. After a few attempts the students are likely to be successful (Filled to near the top without spilling). How did they know the glass was full?



Follow these steps:

1. Ask students how blind people make a cup of tea without burning themselves or making a mess (over-filling the cup with hot water).
2. Give the students a chance to try and fill the glass with their eyes closed (or blind-folded). They will soon realise that the sound of the water as it fills the glass can tell them how full the glass is. Then ask why the sound changes.

So what happened?

As the glass fills the height of the air column (α) decreases. and this determines the frequency (and the pitch). As the height decreases the pitch increases. Thus we can associate the sound we hear with how full the glass is.

What next?

1. Investigate how musical instruments produce different notes.
2. Make pan-pipes from bottles or jam jars, each filled to a different depth.

Lego harmonics

Generating harmonics of a fundamental frequency

You will need....

✓ A Lego set with a variety of gears, a motor and a battery or power supply.

Background:

If a piece of paper or card is held against the spokes of a rotating wheel or the teeth of gear wheels, notes of different frequency can be heard as the speed of rotation changes.

The ratios of the frequencies of the first six harmonics are: 1 : 2 : 3 : 4 : 5 : 6.

These correspond to the notes d_1, d, s, d^1, m^1, s^1.

Follow these steps:

1. In the assembly shown in the picture, one axle has wheels with 40, 24, 16 and 8 teeth respectively. The 8-tooth wheel is driven by a 24-tooth wheel which is attached to the motor.

So what happened?

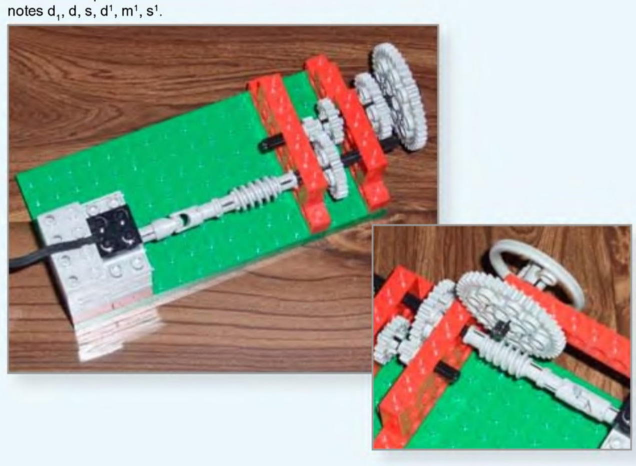
Holding a piece of paper against these wheels generates notes whose frequencies are in the ratio:

1 : 2 : 3 : 5.

These correspond to the notes : d_1, d, s, m^1.

What next?

1. Experiment with other sets of gears to generate the first six harmonics.
2. Add a worm gear to drive a pointer so that the rate of rotation can be easily measured. This can be used as a direct measurement of the frequencies.
3. For a more difficult challenge try to generate frequencies in the ratio: 1: 9/8: 5/4: 4/3: 3/2. These correspond with the notes: d, r, m, f, s.



Waves and sound

Sounds interesting

Speed of sound in carbon dioxide

You will need....

- ✓ measuring cylinder
- ✓ variable audio frequency generator
- ✓ small speaker
- ✓ connecting leads

Background:

The lowest resonant frequency for a column of air in a pipe or cylinder that is closed at one end has a wavelength of four times the length of the pipe.



Follow these steps:

1. Connect the speaker to the audio frequency generator and hold it over the closed pipe or measuring cylinder. Vary the frequency and find the two lowest resonant frequencies; these produce standing waves of one quarter and three quarters of the corresponding wavelengths. Record the frequencies.
2. Add carbon dioxide to the cylinder and record the new resonant frequencies. They are clearly lower than the corresponding resonant frequencies for air.
3. The speed of sound in each case can be calculated as follows: for the lowest resonant frequency $c = f.(\ell \times 4)$. For the next resonant frequency $c = f.(\ell \times 4/3)$.

So what happened?

As the frequency is varied the volume of the sound rises sharply at the resonant frequencies. For a pipe that is closed at one end the resonant frequencies occur when the length of the pipe is an uneven multiple of a quarter wave – 1/4, 3/4, 5/4, 7/4 etc.

What next?

1. If dry ice is used and the temperature of the gas is monitored then the variation of the speed of sound with temperature can be recorded.
2. Using $c = f.(\ell \times 4)$, a better estimate of the velocity is found if ℓ = the length of the pipe + 0.4 d, where d is the diameter of the pipe.

Sounds nuts

Spinning a nut in a balloon creates cosmic sound effects

You will need....

- ✓ A balloon
- ✓ A nut from a bolt of any size

Background:

Due to centripetal force the nut spins around the inside of the balloon. As it rolls the six sides of the nut strike the wall of the balloon and produce a note.

Follow these steps:

1. Place the nut in the balloon.
2. Blow up the balloon and tie the neck.
3. With a swirling movement roll the nut around inside the balloon.

So what happened?

The frequency depends on the rate of spinning:

fast: high pitched;
slow: low pitched.

What next?

1. Experiment with different sized balloons, different objects such as coins and mints with holes.



Waves and sound

String in your ears

Sound travels through materials

You will need....

- ✓ 1 length of string
- ✓ Metallic objects
- ✓ Spoons, coat hanger etc

Background:

This is an interesting way to observe the natural frequencies of objects – and to look foolish at the same time.

Follow these steps:

1. Tie a loop in the middle of the string to hold the object.
2. Wrap the ends of the string around each index finger and put the fingers in your ears
3. Lean forward so that the object does not touch the body.
4. Get someone to strike the object. Listen to the sound.

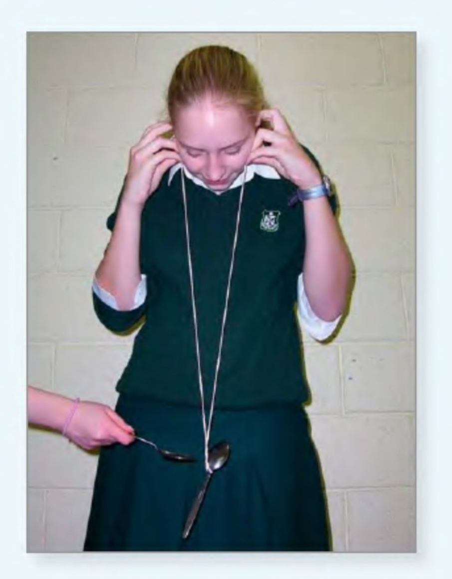
So what happened?

The sound waves from the object travel along the string and a bell-like sound is heard.

The fingers absorb higher frequencies.

What next?

1. Try striking different objects such as a wire coat hanger etc.
2. Try hanging the object in water whilst striking it.



Musical sticks

Standing waves in rods

You will need....

✓ Eight wooden spars or dowels ranging in length from 140 to 200 mm; wood of 10 mm × 10 mm section is very suitable

Background:

The resonant frequency of a rod is inversely proportional to square of the length; if the length is doubled the frequency drops by two octaves. To increase the frequency by one semitone the length should be reduced by about 3 % (2.93 %).

Follow these steps:

1. Cut eight wooden spars of the following lengths: 198, 192, 182, 171, 162, 157, 148 and 140 cm.
2. Ideally the pieces of wood should be as uniform as possible; however it may still be necessary to 'tune' them. Sanding the end of a stick will reduce the length and raise the pitch; sanding the middle will lower the pitch.
3. Drop the sticks onto a hard surface in order of decreasing length.



So what happened?

When only one stick is dropped it does not sound very musical. When the sticks are dropped in order of their length then the changing pitch of the notes is quite obvious. When the wood hits the floor it vibrates for a moment before coming to rest. It does not produce a pure tone but the dominant frequency is more evident when the sticks are dropped in sequence.

What next?

1. Investigate the relation between the thickness of the wood and the frequency.
2. Experiment with other materials such as metal and stone.
3. Make a xylophone: Drill two holes (2 mm diameter) in each piece of wood at a point 22.4 % from each end and arrange them in order on two strings with small spacers between them (e.g. beads or pieces of light plastic tubing).

Modelling planetary motion

Make a computer orrery

You will need....

✓ A PC or Mac running Excel. The spreadsheet is quite small and uses a simple macro to increment the days.

Background:

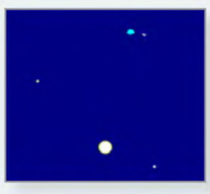
Mercury, Venus and Earth orbit the Sun in about 88, 225 and 365 days respectively with radii of 58, 108 and 150 million km.

Follow these steps:

1. Set up the spreadsheet as shown below. The numbers in red are constants. Four cells in column B have formulas that can be copied across to columns C and D.
2. B4: **=C1/B3**
   B6: **=$A6*B4**
   B8: **=B5*COS(B6)**
   B9: **=B5*SIN(B6)**
3. Select cells B8:D9. Click the Chart Wizard and select the first option under X-Y Scatter.
4. Double-click the gridlines and set the range at -200 to +200 for both axes. The 'Sun' can be drawn manually or added to the chart 'Source Data' with coordinates 0,0. Lastly, remove the gridlines.

The Macro

1. A macro is used to animate the model.
2. Go to Tools/Macro/Record a New Macro. Assign it to Ctrl-K.
3. Select cell A1. Go to Edit/Copy.
4. Select cell A6. Go to Edit/**Paste Special** and choose **Values** and **Add** then click OK.



5. Then **Stop** the macro recording.
6. Pressing Ctrl-K will now animate the model!

So what happened

It models the movement of the first three planets and the Moon.

What next?

1. The colour and size of the dots can be individually changed in Excel.
2. Add a column for the Moon. Note that its calculated coordinates must be added to the coordinates of the Earth; otherwise the model will show it orbiting the Sun.
3. The model neatly illustrates, for example, the distinction between a sidereal month (27.32 days) and a synodic month (29.53 days). The Moon completes a 360° orbit of the Earth in 27.23 days but full moons occur every 29.53 days.

	A	B	C	D
1	1		6.2831854	= 2pi
2	day	Mercury	Venus	Earth
3	Year (Y)	87.97	224.7	365.256
4	Inc.	0.07142418		
5	Radius	58	108	149.6
6	0	0		
7				
8	x	58.00		
9	y	0.00		

Equilibrium toys

Show stable equilibrium using paper characters

You will need....

- ✓ Toy templates (Print some clip art and glue it to the card)
- ✓ Scissors
- ✓ Colouring pencils (optional),
- ✓ Weights
- ✓ Glue to attach weights to the back of the cut-outs
- ✓ Kinder Egg shell, paper to make a face, Blu-Tack to secure a weight inside

Background:

A body is more stable when its centre of gravity is as low as possible.





Follow these steps:

1. Cut out the characters shape from paper or card-board and attach enough weight to make them stand.
2. Show the toy standing correctly but don't tell the students that the toy has a weight at the back.
3. Get students to discuss why they think the charac-ters stand without support.
4. Get students to experiment with some basic shapes and other characters until they gain a practical under-standing of what causes one shape to stand freely while another falls over.

So what happened?

The paper characters could stand freely because a weight had been added to the base balancing the clockwise and anticlockwise forces about their centres of gravity.

What next?

1. Students can locate the centre of gravity using plumb lines.
2. Students can make their own toys.
3. Sit a large box (containing a weight in one corner) on a stool with the most of the box hanging over the edge of the stool. Can the students explain why it does not fall?

Miscellaneous

Ionisation trails

Construct an economical cloud chamber

You will need ...

- ✓ ionisation smoke alarm (this contains 0.2 micrograms of americium)
- ✓ 50 ml veterinary syringe
- ✓ piece of sponge or absorbent cloth
- ✓ methanol
- ✓ water

Background:

A radioactive isotope of americium (^{241}Am) has a half-life 432.2 years and decays to neptunium (^{237}Np) by emission of alpha particles. Ions are formed in the air by these charged particles. If the air is supersaturated then the ions act as condensation sites for water vapour. Fleeting tracks of cloud form in the wake of the alpha particles.



Follow these steps:

1. Open the smoke alarm and remove the plate containing the radioactive source.
2. Attach the piece of sponge to the plate and insert it in the syringe.
3. Moisten the sponge with a 50:50 mix of methanol and water.
4. Insert the plunger about 1/3 of the way into the syringe.
5. Seal the syringe.
6. Push the plunger to increase the pressure and then pull it back rapidly to cause a sudden reduction of pressure. The air in the chamber becomes super saturated with the alcohol/ water vapour.
7. Wipe the plastic case with a cloth regularly, the static charge created by this will help to clear the tube of ions; it will also improve the visibility of the trails.
8. The sponge should be kept moist with the methanol-water mixture. If there is too much condensation open the front valve (the needle attachment) and press the plunger fully up and down a few times to clear air in chamber. Then seal it and try again.
9. Make sure that the radioactive source is free of condensation.

So what happened?

Tracks formed when the plunger was pulled and dissipated within a second or two.

Safety

! Do not handle the radioactive material.

What next?

1. Add a small light to illuminate the cloud chamber (e.g. a white LED keyring light is ideal).
2. Attach a piece of black paper or card to one side of the syringe; the tracks will be more easily seen against the dark background. Alternatively, paint one side of the syringe with black paint.

















Miscellaneous

Weight matters

Compare irregular areas by comparing weights

You will need....

✓ photocopies of areas to be compared

Background:

If photocopies of maps are all on the same scale and on similar paper then the weights of the cut-outs are proportional to the areas. If one area is known then the others can be calculated.

Follow these steps:

1. Photocopy the areas to be compared (e.g. a map of Europe) with or without names as desired.
2. Separate the individual items (countries) by cutting along the borders.
3. Record the weight of each one.

So what happened?

When the area of one part is known then the areas of the other parts can be calculated by multiplying the corresponding weights by :

$$\frac{\text{the known area}}{\text{the weight of its cut-out}}$$

What next?

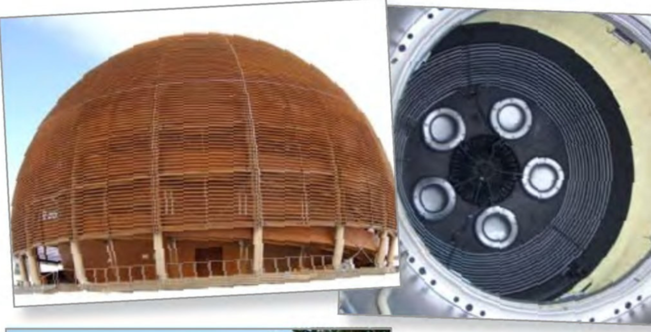
1. This procedure can be used to compare the areas of leaves, the ratio of parkland to built-up areas or of areas of different vegetation or elevation.



INDEX













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